THE HAWAIIAN PLANTERS' RECORD

Volume XXXII. APRIL, 1928 Number 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

P. O. J. 2878

The photograph on the cover indicates the excellent growth which this cane has been making in the quarantine house, in spite of the cool weather during the past months.

Its long, drooping leaves and robust top give it an impressive appearance. It is ahead of a stool of H 109 of about the same age.

Its mother is P. O. J. 2364, a seedling of P. O. J. 100 x Kassoer, and is not itself a commercial cane. Its father, E. K. 28, was the leading cane in Java from 1920 until the present year, when it was obliged to give way to its vigorous offspring.

P. O. J. 2878 was germinated at the Java station in 1921. Seed was distributed to plantations in 1923. By 1925, the results of twenty-six yield trials on different plantations had been reported to the Station. In nineteen of these, P. O. J. 2878 outyielded the standard variety with which it was compared.

In 1926, it had been spread to ¾ per cent of the total acreage in Java; in 1927, to 12½ per cent, and in the present crop to 66½ per cent. It now occupies over 300,000 acres in Java. It is reported to be making a good showing in the Philippines also.

Hawaiian Seedlings—1928 Propagation

The newly propagated seedlings at the Experiment Station this year offer unusual interest. The lot of over 50,000 is made up of over 300 different crosses of known parentage. These include 2,200 seedlings of Kassoer blood. About 1,700 include Kassoer and Yellow Caledonia, a unique combination in sugar cane breeding. There are in all about 5,000 Yellow Caledonia seedlings, a number many times greater than in any previous year. Also, there are approximately 800 Uba hybrids (including the Natal, Porto Rico, and Hawaiian strains) crossed for the most part with H 456. In seedlings of P. O. J. 213 and P. O. J. 234, we have Chunnee quarter-breeds. Finally, it may be said that the Hawaiian-grown seedlings of P. O. J. 2364 (the mother of P. O. J. 2878) carrying Yellow Caledonia blood hold special promise in a season's production which on the whole offers high expectations.

The Retention of Nitrates by Hawaiian Soils

By Guy R. Stewart and Fred Hansson

Since fertilizers were first used upon Hawaiian cane land, the application of nitrogenous salts has given consistently large increases in the yield of cane and sugar. The nitrogen content of either mixed fertilizers or simple salts always represents the greatest money value in the amount expended for fertilizing materials. This does not mean that we are inclined to underestimate the importance of a balanced system of fertilization which supplies adequate amounts of potash and phosphates, as well as nitrogen, at an early stage of the growth of the crop. The experimental evidence which is being obtained by this Experiment Station, and the various plantations in general, indicates the importance of a supply of available nutrients for the young cane plant as soon as it has started active development. But we are especially interested in the matter of nitrogen economy in fertilization, both on account of the large return given by the proper use of this nutrient and by the large percentage of our fertilizer cost which is represented by this one ingredient.

The writers have accordingly carried on several field tests upon the retention of nitrates under field conditions in order to try to obtain some experimental evidence of the conditions prevailing. This work has been carried out with the cooperation of George F. Renton, manager of Ewa Plantation, and W. P. Alexander, agriculturist of that plantation.

In the early reports of Maxwell (6) upon the soil investigations carried out at this Experiment Station there is considerable discussion of the retention of nitrogenous salts in soils. As a result of lysimeter tests upon short soil columns, and field observations which showed the rapid movement of water through the more porous soil types, Maxwell advised against the use of nitrate of soda in regions of heavy rainfall or where heavy irrigation was the usual practice. He believed there was a large loss of nitrogen where soluble nitrates were applied, and strongly urged that ammonium sulfate should be applied where there was a possibility of the loss of nitrogen by leaching.

Later field experiments carried out by the agricultural department of this Station and by a number of plantations have shown that excellent increases in cane tonnage were obtained through the use of nitrate of soda as a supplementary source of nitrogen to augment the amount supplied by mixed fertilizers. It should be pointed out that approximately one-third to one-half of the nitrogen content of the mixed fertilizers is derived from nitrate of soda. A study of the factors affecting the retention of nitrate nitrogen is therefore of decided interest in estimating the return from the manurial treatments applied to the Island cane lands.

The senior author has previously shown (10) some evidence of the retention of nitrates in four-foot soil columns of several typical Island soils upon which no

crop was being grown. When heavy irrigations were applied to soil columns which had been fertilized with nitrate of soda, the loss of nitrates from the four-foot columns was very small with the first two irrigations. Later irrigations carried down a portion of the added nitrates into the third and fourth foot of soil and carried away variable amounts of nitrates in the drainage waters. The quantity of nitrates lost in the drainage varied with the soil type. With the most retentive soil there was no loss of added nitrate above the amount of nitrate nitrogen leached out of an unfertilized soil. In the case of less retentive soils the total loss of added nitrogen ranged from 25 to 35 per cent of the amount put on.

Peck (8) has previously carried out a series of lysimeter studies, with shorter soil columns, using several typical Island soils. There was some evidence of the retention of nitrates in his results. This soluble form of nitrogen was not washed out of the soil with the rapidity which might be anticipated.

There are several factors which might influence the retention of nitrates in a soil, but the most important of these is the power of adsorption which colloidal particles possess. In the early study of colloids, the attempt was first made to distinguish between soluble materials such as potassium sulphate or sodium chloride, which were called crystalloids, and bodies, such as starch or glue, which were called colloids. This distinction is no longer made. It is now known that a large number of materials can exhibit colloidal properties if they are in a sufficiently finely divided condition. These colloidal properties depend primarily on the small size of the ultimate particles of the colloid. A large number of the materials which are most commonly used in ordinary life depend for their value upon the colloidal nature of the particles composing the substance. Prominent among such colloidal products are milk, paints, mayonnaise, glue, starch, ink, bread dough, and innumerable other materials which are handled in everyday life.

An important colloidal property is the ability which finely divided solids possess to adsorb varying amounts of soluble salts from solutions passing through the solid so that the solution which has passed down through such a colloid contains less of the soluble salt than was originally present. This phenomenon of adsorption is largely a physical phenomenon, though certain of the ions of the salts present in a solution may actually react with the colloidal particles.

Our Island soils have a comparatively high content of colloids. These are the finely divided clay-like and silty portions of the soil which give the volcanic soils their characteristically open, spongy texture.

Besides these inorganic colloids, our Hawaiian soils all contain more or less organic colloidal material, which has accumulated in the soil as a result of the decomposition of plant residues. The physical state of these inorganic and organic colloids will have a tremendous effect on the permeability of a soil. The investigation of Hissink (3), Gedroiz (1), Kelley (4), have shown clearly that the finely divided colloidal material of the soil possesses the property of reacting with cations such as calcium, magnesium, sodium ammonium and potassium. This subject of the effect of these replaceable bases on the soil structure was discussed in some detail by Hance and the senior author (2) in the October *Record*. We shall only point out at this time that normal agricultural soils which are in good physical condition and are permeable to air and water, ordinarily contain appreciable quantities of re-

placeable calcium which is held by the colloidal portion of the soil. We have found that puddled, deflocculated Island soils may be caused by an excessive quantity of replaceable sodium or magnesium which has displaced the calcium, which should be present in the soil colloid. The opinions of investigators of the phenomena of base exchange differ as to whether it is a chemical reaction or an adsorption effect. A great deal of evidence indicates that base exchange partakes of the nature of a chemical reaction. It is at least evident that the cations or basic radicals of a fertilizer salt may be fixed in the colloidal complex of the soil if the particular cation is present in greater amount than the soluble calcium of the soil solution. Should the cation be fixed in the soil colloid it will displace an equivalent amount of replaceable calcium. The displaced calcium and the ion, which was formerly combined with the displacing base of the fertilizer salt, would tend to be carried directly out of the soil in the drainage water, were it not for the adsorptive power of the fine particles of the soil colloid.

In the case of nitrate of soda, if this salt is applied to the soil, it will go into solution as soon as it comes in contact with rain or irrigation water. This will make a very dilute solution which will pass down into the soil solution. If the amount of nitrate of soda present in the soil solution is sufficiently small the salt will ionize or separate completely into sodium ions and nitrate ions. Where the sodium ion is present in greater proportion than calcium in the soil solution, the sodium ion or basic radical will tend to displace an equivalent amount of calcium. Where the soil solution contains an excess of soluble calcium the replacement by sodium will be very slight. The nitrate ion would tend to pass directly out of the surface soil and be carried away in the drainage water were it not for the adsorptive effect of the finely divided particles of the soil colloid. This adsorption is likely to be sufficiently great in our colloidal Island soils so that the nitrate radical and the base associated with it will be partially removed from the soil solution. The drainage water passing out of the soil will always contain some nitrates, but we have good theoretical grounds for believing that the amount of nitrates lost in the drainage water will be appreciably less than the amount originally present in the surface soil.

The effect of colloidal adsorption in retaining soluble salts will not be a permanent one. Later irrigations or rains may tend to carry away part of the adsorbed salts, but the extraction of nutrients by the plant roots has been shown by the senior author and others to occur at an early stage of growth in cereal crops (9). There is, therefore, every reason to believe that even a temporary adsorption of fertilizer salts will greatly increase the economical use of nitrogenous salts.

Experimental evidence of the adsorption of nitrate of soda by colloids is given by the work of Osaka (7), where he studied the relative adsorption of potassium iodide, potassium nitrate, sodium nitrate, potassium chloride, sodium chloride, potassium sulfate and sodium sulfate by blood charcoal. In the case of this blood charcoal no base replacement could take place. Retention of the salts could only be due to adsorption. Osaka found that the order of retention of the above salts was in the order above listed, that is, potassium iodide was most adsorbed, followed by potassium nitrate and then sodium nitrate.

It is very probable that the retention of a salt by adsorption will vary greatly with different soils. Differences in colloidal content between individual soils will, of course, be an important factor, but the relationship of the various salts present in the soil solution will also exercise an appreciable influence. This is clearly shown by the work of Lachs and Michaelis (5), among others, upon the adsorption of combinations of salts by charcoal. In some cases the addition of a second or third salt notably increased the adsorption, while in other instances it was decreased.

The above resume is not intended to be exhaustive, but merely gives some of the theoretical considerations involved in the study of the retention of fertilizer salts by soils.

Experimental Work

The experiments so far conducted in the field have been carried on at intervals in a period extending over several years. The work reported here has been done upon several different types of soil at Ewa Plantation. The following three fields were used in our first experiments: Field 6, where the surface soil is a brown, silty clay loam, underlain by a deep brown clay loam subsoil; Field 22, which has a red silt loam soil, underlain by a coral rock at a depth of 16 to 24 inches; Field 26, where the surface soil was a brownish black clay adobe, underlain by an even more compact clay subsoil. In the third and fourth foot of this subsoil there was a considerable amount of gypsum crystals, which would indicate that this soil had been deposited in a tidal flat, which was later isolated from the ocean, and subsequently elevated.

In our experiments in these fields, the cane grown was the H 109 variety, which was about six months of age. A uniform plot of land was chosen and a series of twelve surface soil and subsoil samples were taken at each sampling by means of soil augers. Each boring in Fields 6 and 26 was taken to a depth of four feet, each foot being kept separate and analyzed for moisture, nitrate nitrogen, ammonia nitrogen and nitrite nitrogen. In Field 22 the same procedure was followed, except that sampling could not be carried below 16 inches to 24 inches in depth.

After the preliminary samples were collected, sodium nitrate was applied at the rate of 650 pounds per acre, which supplied 100 pounds of nitrate nitrogen per acre. The plots were then irrigated and soil samples were collected in the same manner as the preliminary set. After each set of samples was taken, care was exercised to fill all the sample holes tightly with earth, in order to prevent subsequent irrigations from running down, through these holes, into the lower soil. In these preliminary studies we did not carry out observations upon an unfertilized plot, owing to lack of analytical assistance. This was done, however, in a later study in Field 1 C, and the results upon the movement of nitrogen are so similar that we believe we are justified in drawing certain general conclusions from the earlier experiments.

In order to make the voluminous analytical results available for ready study we have averaged the figures obtained upon the twelve separate samples for each foot of soil at each period of sampling. The results for ammonia nitrogen showed only traces were present at any time and there were no significant variations

throughout the experiments. We have, therefore, omitted the reproduction of these results. Small but determinable amounts of nitrites were found in all the soils, but here again the figures were practically constant, so we have omitted those data, which were not found to be significant. The data submitted cover the moisture determinations, nitrate nitrogen and soil reaction, expressed as pH. We shall consider the results for each separate field briefly and then summarize the more outstanding observations.

Field 6: The results cover two fertilizations, one in the late summer and another the following spring. The first fertilization, with 100 pounds of nitrogen per acre derived from nitrate of soda was made August 15. The field was irrigated the following day and then received water at approximately two-week intervals, eight irrigations in all up to November 22, the period covered by our fall observations. The determinations of moisture and nitrogen at each sampling period are given in Fig. 1. It will be seen that the increase of nitrates and moisture is greatest in the first and second foot of soil. There is a slight increase in the third foot and very

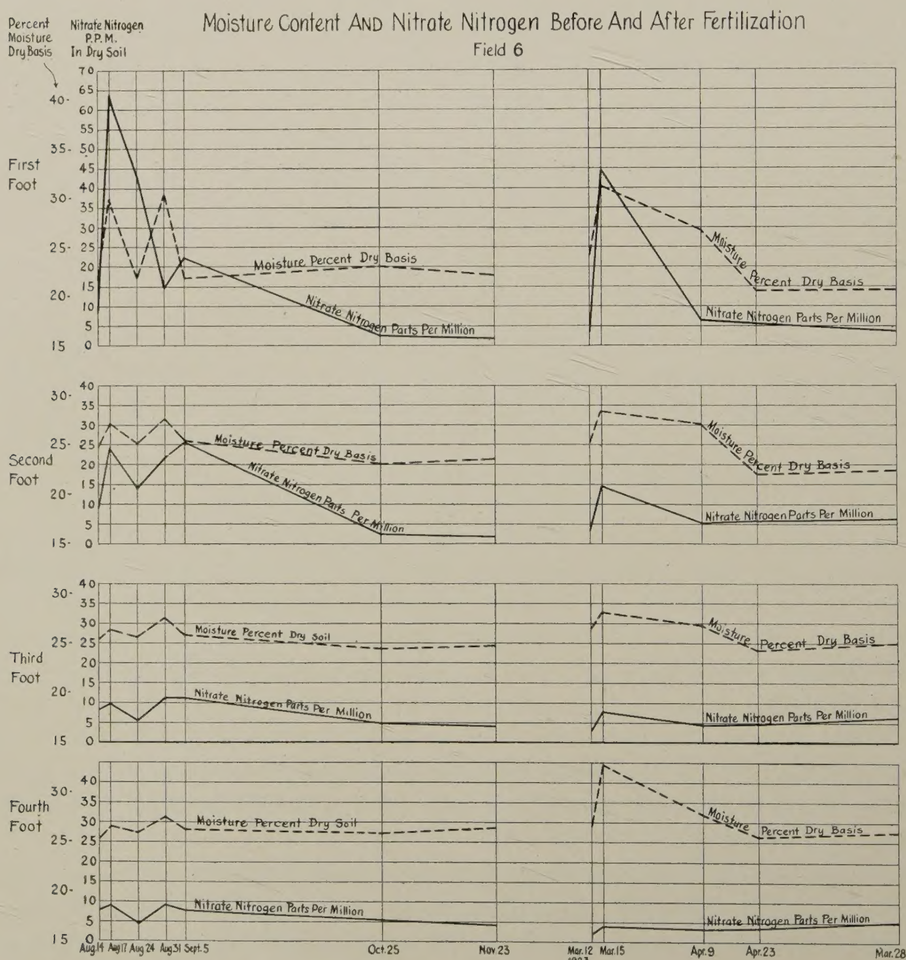

Fig. 1

little change in either constituent in the fourth foot. Our results show that in this experiment both nitrates and moisture were largely retained in the top two feet of soil. The increase of both moisture and nitrates is quite comparable, so we can not state that there was any definite evidence of adsorption or retention of nitrates out of the descending moisture. In the second fertilization, however, there was a greater increase of moisture than of nitrates in the lower soil strata. We are, therefore, inclined to believe that adsorption of nitrates has taken place. The period in which the cane crop reduced the nitrate content of the soil to the same level which prevailed before fertilization was about 10 to 12 weeks after the first fertilization, and a still shorter time elapsed before this happened after the second fertilization.

Field 22 C: The experiment in Field 22 C was started at the same date as Field 6. The subsequent irrigations were slightly less frequent, so that only six applications of irrigation water were made in the period from August 13 to November 22. The determinations of moisture and nitrate nitrogen are given in Fig. 2.

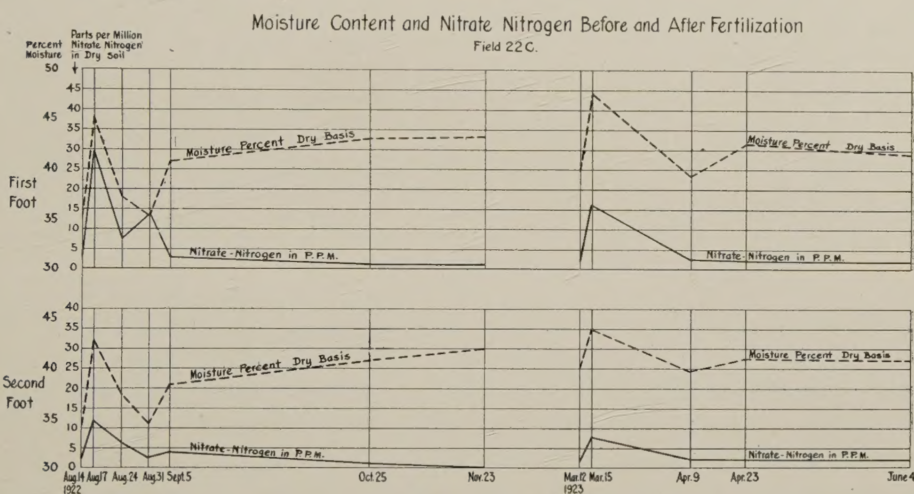

Fig. 2

In this soil there was a smaller increase of nitrates in the second foot than in Field 6 and there was a larger proportionate increase in moisture content in the second foot of soil. This would indicate some adsorption of nitrates in both periods of fertilization. In this shallow soil the nitrates were reduced to the low content which had prevailed before fertilization in a surprisingly short period of time after fertilization. In the fall period about 8 weeks elapsed before the added nitrates were removed, while in the second period the results indicate that only a month had elapsed until the nitrates were reduced to a low content.

Field 26: In this field the first application of 100 pounds of nitrogen per acre was made September 15. The nitrates were reduced to the previous level in about 8 weeks. After the spring fertilization, the added nitrates had disappeared from the soil in a still shorter time. In both cases, as shown in Fig. 3, there is some

evidence of the adsorption of nitrates by the upper layers of this heavy colloidal soil.

Field 1 C: This experiment was designed especially to study the course of nitrate retention in the soil under the growing conditions of the winter season. The control or X plots received no fall fertilization, while the N plot received a fertilization with 100 pounds of nitrogen per acre, derived from nitrate of soda,

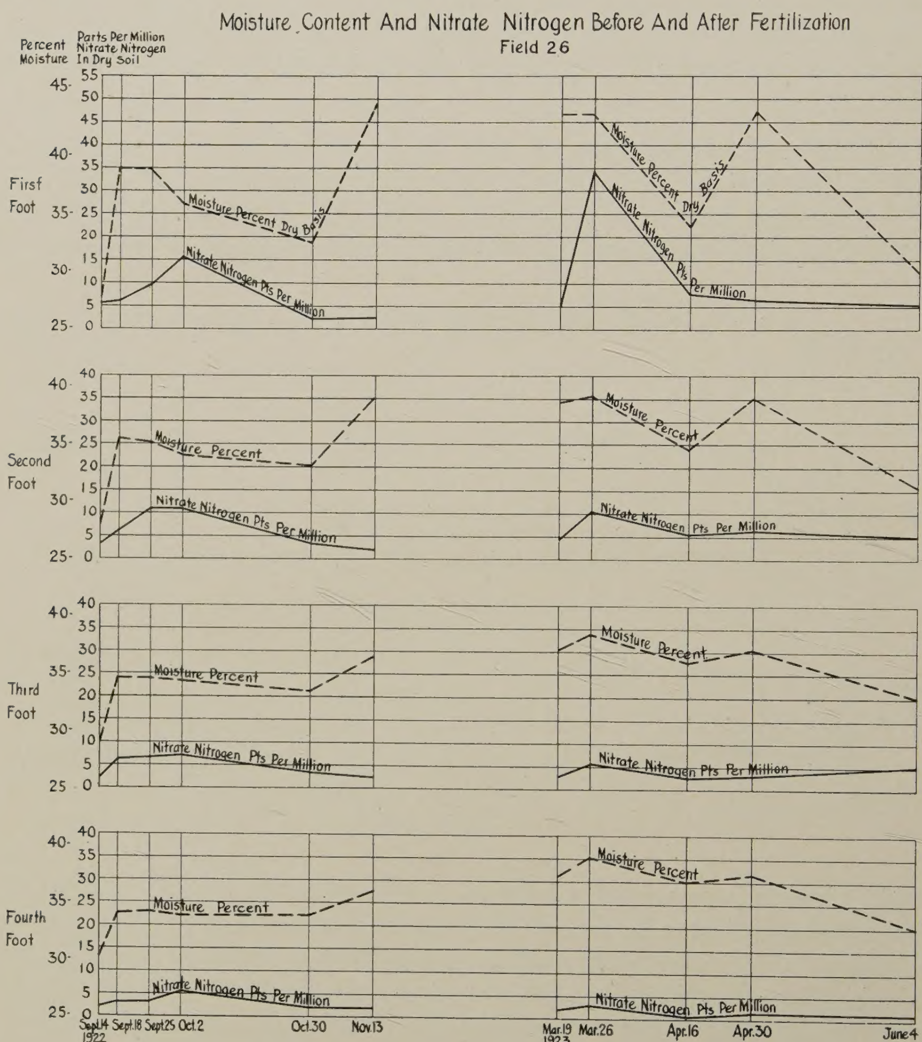

Fig. 3

on November 10. The plots used in this experiment formed part of the overhead sprinkler experiment installed in Field 1 C. The nitrogen was applied by hand and was then followed by a regular irrigation through the sprinkler system. Moisture, nitrates, and soil reaction were determined at frequent intervals throughout the winter months, and the following summer. The X plots received no nitro-

gen until the following spring. On February 11 both the fall fertilized and X plots received 53 pounds of nitrogen per acre. The nitrogen was derived from nitrate of potash and was applied through the sprinkler system, being followed by an after irrigation to wash the soluble nitrates off the cane leaves. A second fertilization of 74 pounds nitrogen per acre, derived from potash nitrate, was applied to both plots on April 1. This was also applied in the irrigation water.

The results of the comparative moisture determinations are given in Fig. 4. It is interesting to note that the soil of the plots receiving the fall fertilization at

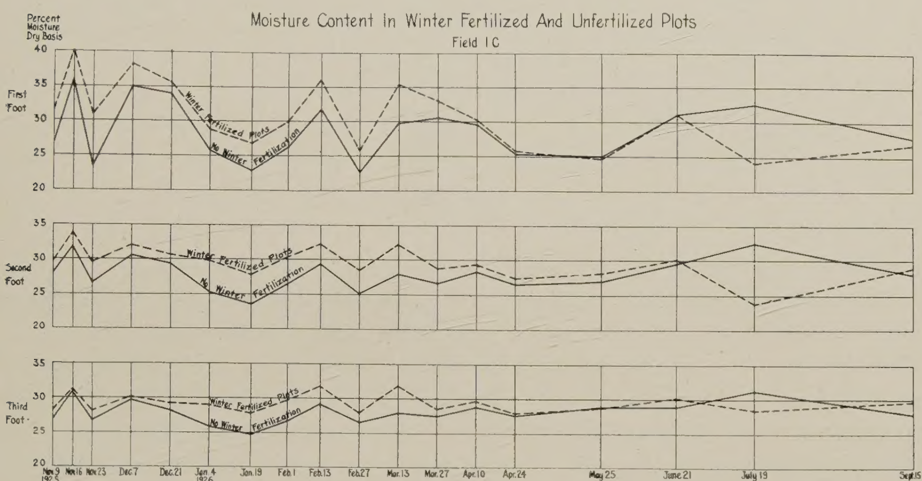

Fig. 4

all times showed a higher moisture content, until after the second spring fertilization. This agrees with the observations made by the senior author (11) in a study of the moisture content of fertilized and unfertilized plots of pineapples, both with and without mulching paper. There are a number of possible explanations of this phenomenon. The effect is so immediate after the fertilizer is applied, that it is doubtful if the effect is due to increased growth and greater shading of the soil of the fertilized plots. It is more probable that the effect is caused by a slight change in the degree of dispersion of the soil colloids and consequent increased retention of moisture.

The nitrate determinations are recorded graphically in Fig. 5. It is very clear that the adsorption of nitrates from the soil of the fertilized plots was not so rapid as in the experiments previously recorded in which nitrogen was applied during the months of more rapid growth. The increased nitrogen content of the soil in the N plot caused by the fall fertilization was sufficiently large so that there is no definite evidence of an increased nitrogen content in the soil of this plot after the February fertilization. The effect of this fertilization is, however, evident in an increased nitrogen content of the soil of the check plot. Neither plot showed any great evidence of an increased content of nitrate nitrogen after the April fertilization, though the nitrates in the soil of the former unfertilized plot are more evident than in the N plot. No further nitrogen applications were made,

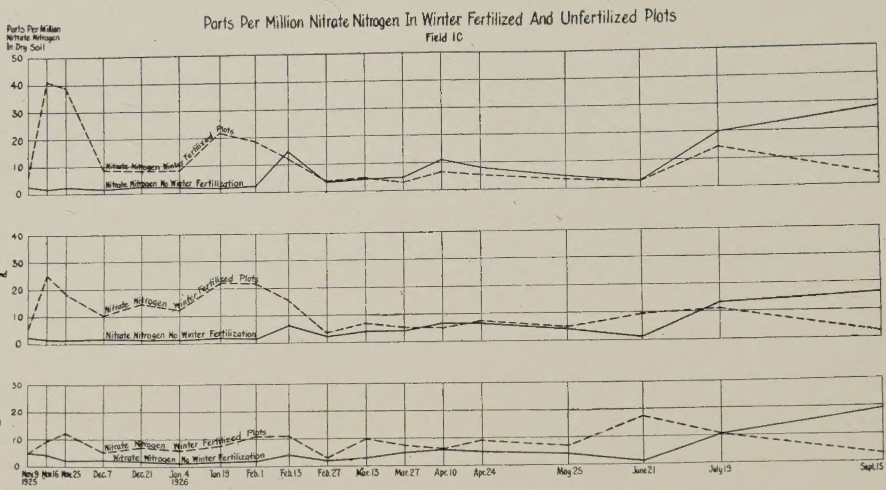

Fig. 5

but there was a noticeable increase in the content of nitrate nitrogen in July. This increase persisted into September. This would point to a rapid stimulation of nitrification of soil organic nitrogen as a result of higher soil temperatures.

The increase in growth caused by the winter fertilization is shown by graphic representation of the average total growth of the two plots in Fig. 6. These measurements were made by the agricultural department of Ewa Plantation. The winter of 1925-26, in which this winter application was made, was an unusually dry winter, so it was probably an exceptionally favorable season for winter growth of cane without heavy rains to remove soluble nitrates from the upper horizons of the soil. In our experiment there is considerable evidence of sufficient adsorption of nitrate nitrogen so that the major portion of the fall application was retained in the upper two feet of the soil column. Under these conditions this late fall fertilization might be considered to be successful so far as nitrate retention is concerned.

Effect of Nitrate of Soda Upon Soil Reaction

It is commonly believed that the continuous application of nitrate of soda will cause a gradual change in the soil reaction so that soils fertilized with this salt over a period of years will tend to become slightly alkaline. The soil samples collected in our soil survey work do not show that there is any great tendency towards the formation of alkaline residues as a result of the application of nitrate of soda. In our present experiments we determined the reaction of all or a portion of the individual soil samples at each sampling period. As this is a subject which has caused a good deal of discussion in the past, we give the average figures for each portion of the soil horizon, at each sampling period in the table. It will be seen that the reaction before and after fertilization is practically the same in every case except one, that is the fall fertilization in Field 22 C. Portions of this soil contain appreciable quantities of lime, and it is believed that the change noted in the pH of the soil is more likely to be due to differences in the lime content of the portions of the plots which were sampled.

SOIL REACTION BEFORE AND AFTER FERTILIZATION

Soil Reaction Field 6
Before and After Fertilization with 650 lbs. Nitrate of Soda
Results Expressed as pH

	Aug. 14 Before Fert.			Aug. 31	Sept. 5	Oct. 25	Nov. 23	Before Fert. Mar. 12	After Fert. Mar. 15	Apr. 9	May 28
First Foot	7.7	7.8	7.9	7.8	7.8	7.9	7.9	8.2	8.1	8.1	8.1
Second Foot	7.6	8.0	7.9	7.8	7.8	7.8	7.7	8.2	8.1	7.9	8.1
Third Foot	7.4	7.8	8.0	7.8	7.8	7.8	7.7	8.0	8.0	7.8	7.9
Fourth Foot	7.4	7.7	7.9	7.8	7.8	7.8	7.8	8.0	7.8	7.8	7.9

Soil Reaction Field 22 C
Before and After Fertilization with 650 lbs. Nitrate of Soda
Results Expressed as pH

	Aug. 14 Before Fert.			Aug. 31	Sept. 5	Oct. 25	Nov. 23	Before Fert. Mar. 12	After Fert. Mar. 15	Apr. 9	May 28
First Foot	7.8	8.3	8.0	8.0	8.1	8.0	8.0	8.5	8.5	8.2	8.3
Second Foot	8.0	8.4	8.0	8.0	8.1	8.1	8.1	8.5	8.1	8.1	8.1

Soil Reaction Field 26
Before and After Fertilization with 650 lbs. Nitrate of Soda
Results Expressed as pH

	Before Fert. Sept. 14	After Fert. Sept. 18	Sept. 25	Oct. 2	Oct. 30	Nov. 13	Before Fert. Mar. 19	After Fert. Mar. 26	Apr. 16	Apr. 30	June 4
First Foot	7.8	7.8	7.8	7.7	7.9	7.9	7.9	7.9	7.8	7.9	7.7
Second Foot	7.9	7.9	7.9	7.8	7.9	7.8	7.9	8.0	7.9	7.9	7.8
Third Foot	7.9	8.1	8.1	7.9	8.2	8.1	8.2	8.1	8.1	8.2	7.9
Fourth Foot	7.8	7.9	7.9	7.8	7.9	7.9	7.9	7.9	8.0	8.0	7.7

Soil Reaction Field 1 C
Soil Reaction of Winter Fertilized and Unfertilized Plots
Field 1 C X Plots No Winter Fertilization

	Nov. 9 1925	No. Fert. Nov. 16	Nov. 23	Dec. 7	Dec. 21	Jan. 4	Jan. 19	Feb. 1	After Fert. Apr. 10	Apr. 24	June 21
First Foot	7.6	7.7	7.6	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.7
Second Foot	7.5	7.5	7.6	7.5	7.5	7.6	7.6	7.5	7.5	7.4	7.6
Third Foot	7.3	7.4	7.4	7.3	7.4	7.5	7.4	7.4	7.4	7.3	7.5

Field 1 C N Plots Winter Fertilized

	Before Fert. Nov. 9 1925	After Fert. Nov. 16	Nov. 23	Dec. 7	Dec. 21	Jan. 4	Jan. 19	Feb. 1	After Fert. Apr. 10	Apr. 24	June 21
First Foot	7.6	7.7	7.6	7.7	7.7	7.7	7.6	7.6	7.6	7.6	7.7
Second Foot	7.6	7.6	7.6	7.4	7.5	7.7	7.5	7.4	7.4	7.4	7.5
Third Foot	7.5	7.4	7.3	7.3	7.3	7.5	7.3	7.2	7.2	7.1	7.3

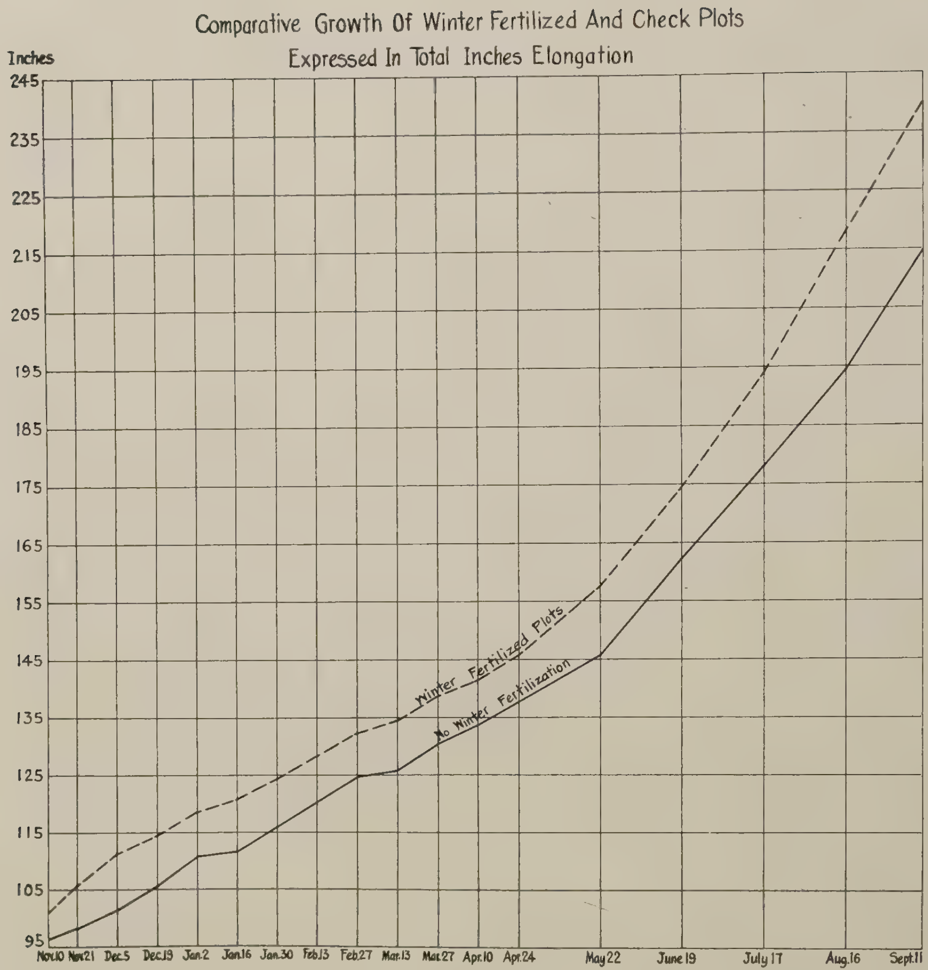

Fig. 6

Summary

1. The experiments recorded here are an attempt to follow the content of soluble nitrogen compounds in several typical Island soils, before and after fertilization with nitrate of soda.

2. Determinations of ammonia and nitrite nitrogen in water solutions showed that there were never more than minute traces of soluble ammonia nitrogen, and constant small amounts of nitrites present in the soils, at the various sampling periods.

3. Determinations of the soluble nitrate nitrogen in all the soils showed an appreciable increase in nitrates in the surface soil after fertilization. There was a smaller increase in the nitrate content of the second foot of soil than was found in the top soil. Slight increases of nitrate nitrogen occurred in the third foot of soil, and still smaller increases were found in the nitrates present in the fourth foot of soil following nitrate fertilization.

4. It is believed that the determinations of nitrate nitrogen, before and after fertilization, indicate clearly that the greater portion of the added nitrates were retained in the upper two feet of the various soils.

5. The relative penetration of moisture and nitrates into the lower horizons of the soils would suggest that part of the retention of nitrates in the upper two feet of soil is due to adsorption by the colloidal complex of the soil.

6. Comparison of the moisture content of fertilized and unfertilized soil shows a small but definite increase in moisture content as a result of fertilization with nitrate of soda.

7. The disappearance of the added nitrates from the soils occurred in eight to twelve weeks when the nitrogen was added in the late summer or early spring season. In the case of the winter fertilization in Field 1 C, the added nitrates had not disappeared in 14 weeks, at which time the spring fertilization was applied. Since the added nitrates were never detected in large amount in the third and fourth foot of soil, we believe we are justified in concluding that the disappearance of nitrates was caused by the extraction of this nutrient through the growth of the cane crop.

8. No determinable change in soil reaction occurred as the result of one or two fertilizations with 650 pounds nitrate of soda per acre, applied to the soils used in our experiments.

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Vitamin-like Substances in Plant Nutrition With Some Comments on Molasses Fertilization

By W. T. McGeorge

There has recently appeared from the Arizona Experiment Station a bulletin by J. F. Breazeale on "Vitamin-like Substances in Plant Nutrition." In view of the local interest being revived in fertilization with molasses, the views expressed in this bulletin on the effect of organic fertilizers are of more than passing interest.

It brings to mind the early work of Bottomley and previous work by Breazeale which demonstrated that in water cultures plant growth is often greatly improved if along with mineral nutrients a water extract of organic material, such as manure or peat, is added. In fact, their observations led to the assertion that soluble organic materials are at least helpful if not essential in plant growth. Bottomley used nucleic acid derivatives from bacterized peat, growth products of *Azotobacter chrococuum* and *B. radicicola,* leaf mould, fresh and rotted stable manure and well manured soil, and found that the water extract of all promoted growth in his plants. Breazeale used dilute extracts of peat and obtained a marked stimulation of root growth in citrus seedlings which could not be obtained with corresponding mineral nutrients.

Bottomley's experiments led him to suggest that plants required growth-promoting accessory factors similar to the vitamins — he called them auximones — needed in human nutrition. A commercial preparation along the above theory, known as "humogen" and prepared from bacterized peat, gave disappointing results at Rothamsted. Later Clark and Roller discovered what appeared to be experimental errors in Bottomley's culture studies, which led them to take issue with his conclusions and to question any basis for the analogy of vitamins.

Discussion of this phase of plant nutrition has been reopened by the recent bulletin by Breazeale. Some of the salient points which he brings out are as follows:

The decomposed remains of most plants possess the peculiar property of stimulating the growth of other plants.

While fermenting, nearly all forms of vegetable matter are toxic, including even stable manure.

It is well known that no crop should be planted upon land immediately after an application of fresh manure or after plowing under a heavy growth of green vegetable matter. While it is true that much benefit is derived from inorganic fertilizers upon field crops, yet there is an "appearance" to a plant growing in a soil which has been manured that is different from that of a plant growing in a soil that has not been so treated.

Crop Rotation and Green Manuring

An adequate supply of stable manure seldom can be obtained on the farm, and it is not always economical to devote a full season's growth to a crop that can be used only for green manuring. For these reasons, in practically all systems of agriculture, and with nearly all cultivated crops, some form of rotation is necessary. With most plants rotation is the order of nature. Natural rotation may be very slow as with the great trees of the forest, or it may be very rapid as with many annuals. Even when the major forest growth appears to

be permanent there is often a rotation going on in the underbrush. When the virgin or hardwood forests of the South are cleared, they nearly always come up in pine timber. Few plants are so constituted that they will grow to advantage in a soil that has been continuously cropped with their own species. There are some exceptions, but it may be said safely that most agricultural crops are benefited by a rotation, and that for certain crops a rotation is almost a necessity.

The application of stable manure, the growing of ''catch'' crops intercropping with cover crops, green manuring and rotation, all accomplish the same beneficial results — all bring organic matter into the soil.

A soil is good only because it has the ability to produce a good crop. A soil may contain plant food in abundance and yet not be a good soil, or a soil may be in excellent physical condition and yet not produce a good crop. The maintenance of fertility, therefore, involves factors other than the supply of plant food or the mechanical condition of the soil.

A plant will often react to a change in soil conditions that cannot be detected by physical or chemical means.

Vitamins in Plant Nutrition

The term vitamin, as applied to plant nutrition, must not be misunderstood. By this term is meant certain organic compounds, not ordinarily considered as plant foods, that are required by plants, and that are effective in exceedingly small amounts.

During the past 25 years the writer has grown, handled and watched many hundreds of thousands of seedlings of different plants in an effort to find out something of their likes and dislikes and of their food requirements, and during this time many phenomena have been observed that cannot be explained by the usually accepted plant food theories. Much fragmentary evidence is at hand that teaches that plants require certain organic compounds, which may be called vitamins, and that are just as necessary in plant life as are other vitamins in animal life.

So much for his comments preceding his experimental data. For his culture experiments he evaporated to dryness a water extract of manure. The black powder which he obtained was extracted with diluted alcohol in order to remove all the inorganic plant foods, and then he redissolved the black residue in water. Using wheat seedlings he obtained a greatly enhanced growth with the solution of the organic material which had been freed from inorganic salts, and no improvement in growth from the alcohol-soluble inorganic material. He thus has shown that the active constituent of manure is the water-soluble organic matter. Further experiments were conducted with citrus with significant results and his comments are of interest. "Cactus and creosote bush having grown for ages on the desert would probably not profit by application of organic matter." But the attempts to grow citrus under the same conditions, which are not the environment of its adaptation, have often met with disaster. Applications of organic matter are now known to be vitally essential in citrus culture of the Southwest. To quote Breazeale further:

Many times has the writer planted healthy citrus seedlings, and given them restricted food ration, consisting of nitrogen, phosphorus and potash, but no organic matter. Symptoms of malnutrition are almost sure to appear. Usually the seedlings may be restored to healthy normal condition by the addition of organic matter, sometimes in exceedingly small amounts. A thimbleful of peat or leaf mould, or a small amount of bog water, when sprinkled upon the top of a pot containing unhealthy citrus seedlings, will often cause the seedlings to turn green and start out anew with a vigorous growth. Undernourished trees a year old have

been converted to normal trees in a short time by the application of small amounts of leaf mould.

In addition to the above he cites the work of McCarrison in India, which showed that millet grown on manured plots was more nutritious and of higher vitamin content than that grown on plots receiving only inorganic fertilizers.

Breazeale's conclusions are:

1. Certain plants, upon decomposing, develop compounds that stimulate the growth of other plants.

2. The stimulating property of manure rests largely in the black, water-soluble organic matter, and not in the plant foods, nitrogen, phosphate or potassium that it contains.

3. From observation on seedlings, it appears that many plants, in order to develop normally, require certain organic compounds in the soil that are usually considered as plant foods. These compounds are effective in exceedingly small amounts, and they are necessary in plant nutrition because they are one of the factors that have made the plant what it is today.

4. The beneficial effects of manuring and crop rotation are due in large part to the fact that vegetable matter develops or sets free certain organic compounds that are essential to the growth of plants.

The question arises, is there any analogy of the above line of reasoning to molasses fertilization? The fertilizer value of this material has been ably reviewed by Moir in the January *Record*. From this we learn that its use is general in Mauritius and to less extent in Java and certain of the West Indian countries.

We learn further that success has only followed its intelligent use; in other words, the adoption of methods which have been arrived at through careful study of conditions under which it has been applied, that is, amounts applied and whether applied to growing cane or while the land is in fallow, and, too, with due consideration to the physical texture of the soil. At first, attempts were made to estimate the value of molasses upon the basis of its plant food content. This falling short led to an inclusion of its effect upon nitrification, ammonification and nitrogen fixation. In reading over the literature on this subject there still appears an air of mystery underlying the enhanced growth obtained on some soils as the following quotations from literature will show:

Considerations drawn from these experiments show that the increases are too large to be attributed entirely to plant food conveyed by the molasses to the soil; consequently, some other contributing cause must be sought. This is probably biological in nature.

Stimulation to nitrogen fixation has been suggested, but experiments do not substantiate this for good soils.

Nitrification is entirely suspended following the addition of molasses, to be resumed later at an enhanced rate.

A repopulation of soil takes place.

The results obtained are superior to those that would be produced by the same quantity of nitrogen and potash in artificial manures. The influence of the molasses would not appear to be exhausted during the first year and seems to make itself *felt for some time.*

In reviewing the literature on fertilizaztion with molasses one significant feature is, to the writer, that the role of yeast has attracted no attention. In the high carbohydrate content of the molasses, we are adding to the soil, compounds which depend largely upon yeast for their chemical destruction. Yeasts are plants, just as much so as sugar cane, requiring nitrogen, potash and phosphate. The

vigorous development and rapid increase in yeast population of the soil would, therefore, take available plant food away from the cane roots and there would necessarily follow an *apparent* injury to cane growth. One of the principal requirements of cane root respiration is a supply of oxygen. Carbon dioxide is the excretory gas of root respiration. The same process applies to yeast plants, and here again may we not have the more actively growing yeast assimilating the major part of the oxygen in the soil atmosphere and poisoning the cane roots with its own respiratory products? In other words, in adding molasses to growing cane there is produced a highly competitive situation in which the cane plant is greatly outclassed in competition with such an actively growing plant as yeast in a carbohydrate medium. This is shown in the injury to growing cane following heavy molasses applications and lack of injury or enhanced growth from light applications. In other words, an overpopulation of yeast plants in the former and a minimum or optimum population in the latter.

All seem agreed that molasses accelerates denitrification and nitrogen fixation but retards ammonification and nitrification. Is this strictly true or only apparent? Rather, may it not be simply a question of terminolgy? Articles published, covering the several phases of molasses fertilization, fail utterly to establish proof of either denitrification or retarded ammonification or nitrification in the usual sense of these terms. True, their observations have shown a disappearance of soluble nitrogen salts. In place of the so-called denitrification and nitrogen fixation by bacteria, may not the above observations (disappearance of ammonia and nitrate nitrogen) be caused by the yeast plant grasping all the available nitrogen in building its own protoplasmic bodies in the form of protein compounds? In the large bread bakeries nitrogen salts are often added to the yeast as food.

Peck found "that after the disappearance of the sugars in the molasses in Series D, the soil was able to regain some of its original powers of ammonification and nitrification; with fresh molasses being applied at two-week intervals, these powers were kept continually in check."

In other words, the yeast plants exhaust, in so far as needed, the storehouse of nitrogen and possibly other forms of plant food in satisfying the needs of their own metabolic processes. The period of activity of the yeast is limited by the amount of carbohydrate supplied in the molasses. When this is exhausted the accumulated nitrogen (or other plant foods) becomes available for the cane, as it is now present in an easily nitrifiable (or available) form.

On these bases are Peck's conclusions, as expressed in Experiment Station, H. S. P. A., Agricultural Bulletins 34 and 39, such a great point for controversy:

1. "Molasses applied at intervals on land on which cane is growing and fertilizer has been applied will work harm by destroying nitrates already supplied in the fertilizer." The writer would accept the above observations as well proven by Peck's investigations, but that the apparent "destroying of nitrates" is a result of the active assimilation of nitrates by the yeast plants. And "preventing of formation of nitrates" of being a result of rapid assimilation of nitrates as formed by nitrification or even as ammonium salts and, therefore, there is no chance for accumulation.

2. "Molasses applied to land lying fallow or at an interval of several weeks to the time of planting of the crop may produce beneficial results by providing a stimulus to the nitrogen fixing bacterial of the soil in a form which can be made readily available to the crop at a later date by the organisms in the soil." This observation is unquestionable in fact, but in theory is more easily explained if we consider yeast rather than bacteria as the principal accessory plant. The store of nitrogen is within the yeast plants in the form of easily available proteins. In applying the molasses during fallow, carbohydrate fermentation is at an end before planting and instead of competition we have the destructive processes supplying plant foods from the dead yeast plants.

Enzymes are among the most active agents in plant metabolism and katabolism. We know little of their composition, but much of their properties. They are believed to be of complex organic nature. Breazeale's interpretation of plant vitamins — auximones — as essential organic compounds would include enzymes. They are abundantly formed in the growth of the yeast plant.

The vitamin B of animal nutrition is pre-eminently present in yeast. The fact also that it is present in green leaves, growing parts of plants, and in the germs of grains and seeds may or may not be a significant analogy. The so-called vitamins of human nutrition are also complex organic compounds of little known composition.

Many other organic compounds are of possible formation in molasses fermentation. The Java Experiment Station reports that "the organic matter of molasses cannot be placed on a par with that resulting from the decay of vegetable matter. It is almost exclusively in the form of sugars which ferment and disappear very quickly in the soil without leaving anything behind which can be compared with humus." The writer would seriously question any grounds for such a broad conclusion. The final products of organic decomposition in soils depend so greatly upon side reactions — as in molasses the nitrogen compounds in the millions of yeast, bacteria and fungi formed during fermentation — that a vast number of organic compounds are possible of formation.

It is not overspeculative to suggest that the extended beneficial effects of molasses residual of the active fermentation period may be due in part to growth-promoting organic compounds such as found by Breazeale.

Identification of Sugar Cane Rust Mite or Stalk Mite

By C. E. Pemberton

A paper by Stanley Hirst, of the British Museum of Natural History, in *Bulletin of Entomological Research,* Vol. III, pp. 325-328, London, 1912, gives an account of a mite injurious to sugar cane in Barbados, with a careful description accompanied by good figures. Hirst considered this a new species and described it as *Tarsonemus spinipes* sp. n.

Minute comparisons of our common stalk mite with these figures, in December, 1927, indicated no difference between the species in Hawaii and that in Barbados. Our species has formerly been assumed to be *Tarsonemus bancrofti* Michael, a mite described from Queensland and listed from Java, Mauritius and Barbados. Specimens of our mite were sent to the British Museum in December for comparison with Hirst's type material of *Tarsonemus spinipes* from Barbados. Under date of February 1, 1928, we have received a communication from Susan Finnegan, of the British Museum, stating that our specimens agree with Hirst's type of *Tarsonemus spinipes.* Our mite then, must henceforth be *Tarsonemus spinipes* Hirst, and not *T. bancrofti* Michael.

We have formerly assumed that our species was different from *T. spinipes,* because the latter has been described in Porto Rico by Smyth (*The Journal of the Department of Agriculture of Porto Rico,* Vol. III, Part IV, p. 92, 1919) as especially attacking Yellow Caledonia cane. As it does not become numerous on Yellow Caledonia in Hawaii, it has been believed that our species might be different. Recent examinations, however, of Yellow Caledonia in Honolulu, showed the mite nearly always present on the cane, but never in injurious numbers. It is possible that climatic or growth conditions for Yellow Caledonia in Porto Rico may in some unknown way favor the mite there. The mite is highly sensitive to slight differences in the texture of different cane varieties. Some examinations of cane varieties in Honolulu during January showed wide differences in susceptibility to *tarsonemus* attack and are summarized below:

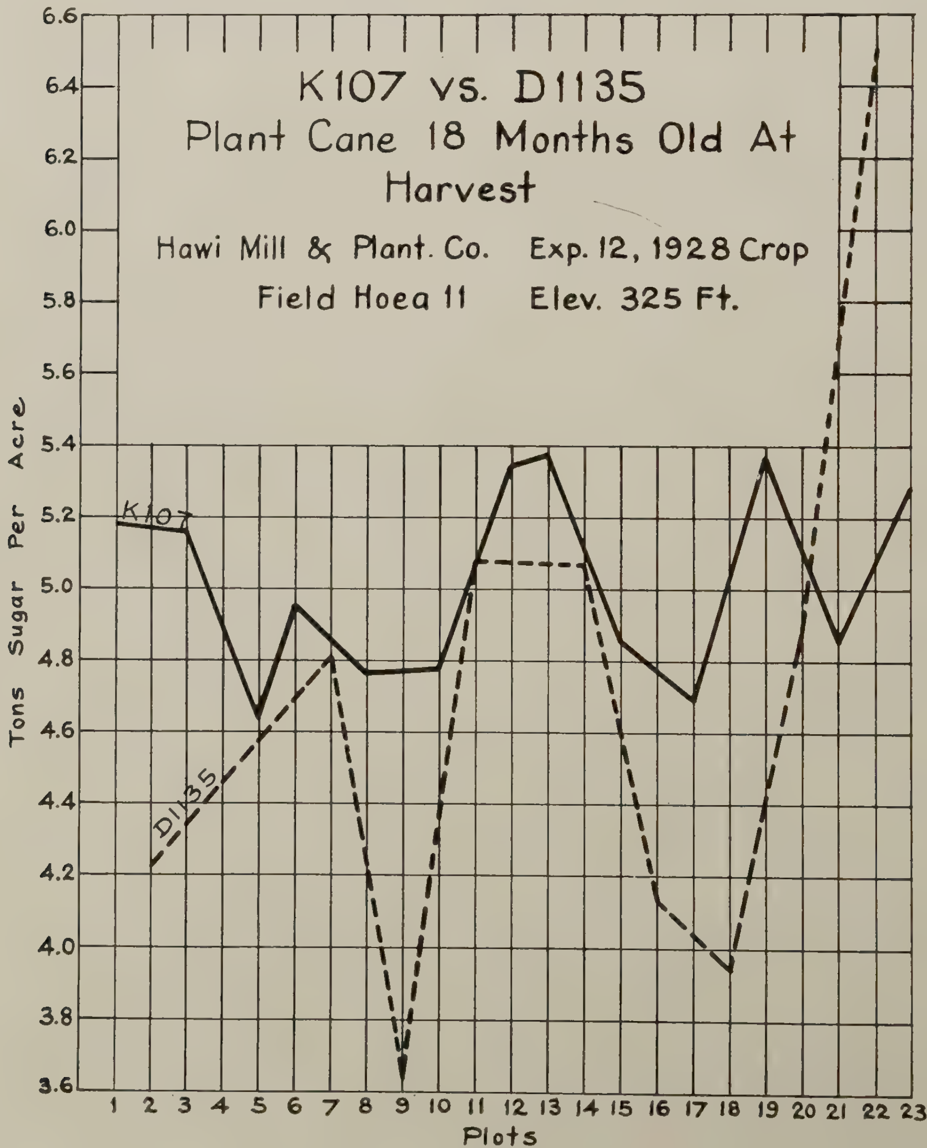
U. D. 1	*Tarsonemus*	rare
Uba	"	"
U. D. 110	"	"
Badila	"	uncommon
Lahaina	"	"
P. O. J. 979	"	"
P. O. J. 234	"	"
Kassoer	"	"
Yellow Caledonia	"	"
P. O. J. 36	"	fairly common
H 8965	"	"
U. D. 13	"	"
Yellow Tip	"	common
H 109	"	"
D 1135	"	"
Striped Mexican	"	"
27 C 429	"	very common

Kohala 107 Shows Up Well in Large Test

HAWI MILL & PLANTATION COMPANY, EXPERIMENT 12

By J. A. Verret

The cane in this test was planted July 16, 1926, and harvested in January, 1928. The field was an irrigated one at an elevation of 325 feet. The layout consisted of twenty-three plots with a total area of 3.2 acres. Each plot was two water-



courses in size. All plots received uniform fertilization in accordance with the plantation practice.

K 107 shows consistent gains over adjoining D 1135 plots. This is true in all cases except one. (See graph.) D 1135, plot 22, gave the abnormally high yield of 63 tons per acre. This is much higher than the yield of any other plot. We believe this to be an error or due to much better soil conditions than those met with in the rest of the experimental area. But we did not omit this plot from the calculations, and the gain of K 107 over D 1135 was in spite of this exceptionally high yielding plot of D 1135.

The behavior of K 107 in rather extensive field plantings shows this cane to be resistant to eye spot, mosaic and red stripe. It ratoons well and closes in somewhat faster than D 1135. As a rule it is not a free tasseler.

Reports to date indicate that by next year, K 107 will be planted to over 1,000 acres.

The summary of the harvest and the detailed yield by plots are given as follows:

HAWI MILL AND PLANTATION COMPANY

Experiment No. 12, 1928 Crop, January 30, 1928.

Object: Variety test, comparing K 107 with D 1135.
Layout: Plots consist of two watercourses each, areas are irregular, total area 3.2159 acres.
Location: Field Hoea 11, elevation 325 feet.
Cane: K 107 and D 1135.
Fertilization: Uniform by plantation.

Harvesting Results — Summary

Variety	No. Plots	Average Tons Cane Per Acre	Q. R.	Average Tons Sugar Per Acre
K 107	13	47.6	9.5	5.02
D 1135	9	45.	9.8	4.6
In favor of K 107		2.6	.3	.42

Experiment carried out by A. J. Watt, Jr.
Experiment harvested by A. H. Cornelison.

HARVESTING RESULTS IN DETAIL

Plot No.	Variety	Area	Tons Cane Per Plot	T. C. P. A.	Q. R.	T. S. P. A.
1	K 107	.1917	9.441	49.248	9.5	5.184
3	K 107	.1677	8.230	49.075	9.5	5.166
5	K 107	.1095	4.829	44.100	9.5	4.642
6	K 107	.1164	5.474	47.027	9.5	4.950
8	K 107	.1301	5.882	45.211	9.5	4.759
10	K 107	.1061	4.809	45.325	9.5	4.771
12	K 107	.1130	5.728	50.690	9.5	5.336
13	K 107	.0856	4.364	50.987	9.5	5.367
15	K 107	.0993	4.576	46.082	9.5	4.851
17	K 107	.1472	6.555	44.531	9.5	4.687
19	K 107	.1267	6.453	50.931	9.5	5.361
21	K 107	.1198	5.515	46.035	9.5	4.846
23	K 107	.1575	7.896	50.133	9.5	5.277
Averages				47.644	9.5	5.075

2	D 1135	.1780	7.370	41.404	9.8	4.224
4	D 1135	.1437	Cast out due to error by labor.			
7	D 1135	.1232	5.809	47.151	9.8	4.811
9	D 1135	.1369	4.874	35.602	9.8	3.633
11	D 1135	.1198	5.963	49.774	9.8	5.078
14	D 1135	.0856	4.252	49.673	9.8	5.068
16	D 1135	.1164	4.709	40.455	9.8	4.128
18	D 1135	.1506	5.834	38.738	9.8	3.953
20	D 1135	.1301	6.212	47.747	9.8	4.872
22	D 1135	.1267	8.076	63.741	9.8	6.504
Averages				45.032	9.8	4.595

In arriving at the tons of cane per plot, every bundle was weighed.

Juice analysis was carried out by Mr. Richmond, plantation chemist, with results as tabulated below:

Car	Variety	Brix	Temp.	Pol.	C. Brix	C. Pol.	Pur.	Q. R.	C. R.
87	K 107	18.7	23	64.1	18.38	15.53	84.4	8.9	9.03
23	K 107	17.6	23	57.9	17.28	14.09	81.5	10.1	10.19
55	D 1135	17.6	25	59.9	17.42	14.37	82.5	9.8	9.92

Iron Sulphate Spray for Coral Chlorosis

EWA PLANTATION COMPANY, EXPERIMENT 1, 1928 CROP

By J. A. Verret

This experiment was conducted by the Ewa Plantation Company and the Experiment Station, H. S. P. A.

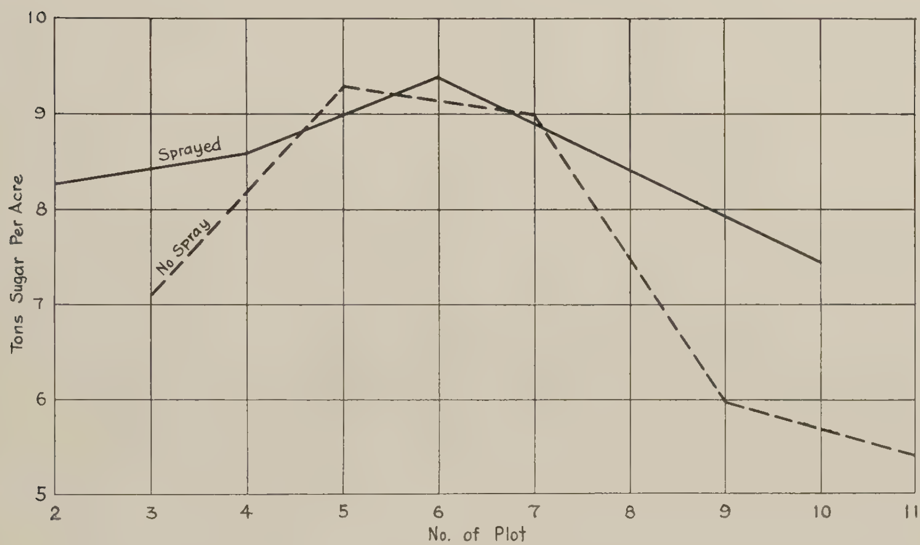
The test was in Field 9A, in one of the so-called coral areas. The cane was H 109, first ratoons, and was 21.5 months old when harvested on January 6, 1928. The layout consisted of eleven watercourse plots of irregular size.

The cane received but one spraying, on June 18, 1926, when 3 months of age. The spray was applied in the form of a 5 per cent solution at the rate of 18 pounds of iron sulphate per acre. The labor for this spraying was at the rate of 0.493 man-day per acre and the iron sulphate cost 30 cents per acre.

Growth measurements were started on June 29, 1926, and carried on at two-week intervals until September 21, 1926. The measurements were taken on ten stalks per plot. Growth measurements in a test of this kind are not satisfactory in that it is not possible to get average stalks. Many of the diseased stalks do not grow at all, and finally die. The figures are given for what they are worth:

	June 29 to July 13	July 13 to July 27	July 27 to Aug. 10	Aug. 10 to Aug. 24	Aug. 24 to Sept. 9	Sept. 9 to Sept. 22	Total growth during period
Sprayed	0.30′	0.38′	0.43′	0.75′	0.43′	0.68′	2.97′
Unsprayed	0.19′	0.27′	0.34′	0.65′	0.47′	0.69′	2.61′

We note that from June 29 to August 24 the sprayed plots made considerably more growth than the unsprayed plots. From September on, the rate of growth was the same throughout the area. This is explained by the fact that by this time the majority of the chlorotic stalks in the unsprayed plots had either recovered or died.



On March 3, 1927, a stalk count was made. Only full lines were taken, and the outside lines were not counted.

The results of this count are interesting:—

Plot	9 — No spray	= 61	stalks per line	
"	10 — Spray	= 77	" " "	
"	3 — No spray	= 79	" " "	
"	2 — Spray	= 90	" " "	
"	5 — No spray	= 82	" " "	
"	4 — Spray	= 87	" " "	
Average No spray plots		= 74	" " "	
Average Spray "		= 85	" " "	
Difference		= 11	" " "	

This shows a difference of 13 per cent less stalks in the unsprayed plots. This difference in favor of the sprayed plots was noted in all the plots counted. We feel that in an experiment of this kind, a stalk count is a more accurate indication of actual conditions than are growth measurements.

Ewa Plantation Company computed the results of the harvest and commented as follows:

SUMMARY OF HARVESTING RESULTS — YIELD PER ACRE

Treatment	Cane	Q. R.	Sugar
	(General — True Average)		
Iron sulphate spray	83.52	9.95	8.39
No spray (Base)	72.75	9.91	7,34
Gain or loss for sprayed plots	+10.77	—0.04	+ 1.05
% Gain or loss for sprayed plots	+14.80%	—0.40%	+14.31%
	(Arith. Average — Adjacent Plots)		
Iron sulphate spray	84.12	9.99	8.42
No spray (Base)	73.11	9.97	7.33
Gain or loss for sprayed plots	+11.01	—0.02	+ 1.09
% Gain or loss for sprayed plots	+15.06%	—0.20%	+14.87%

PLOT-TO-PLOT COMPARISON

	Total	For Sprayed	Same	For Not Sprayed	Odds
Cane	7	5	0	2	19.5 : 1
Quality Ratio	7	4	0	3	9.42 : 1
Sugar	7	5	1	1	......

NITROGEN — RATE OF APPLICATION (SAME AS FIELD APPLICATION)

Age	4.7 Mos.	5.8 Mos.	11.4 Mos.	13.2 Mos.	
Date Applied	Aug. 12/26	Sept. 15/26	Mar. 4/27	Apr. 28/27	Total
Nitrogen (Lbs.)	51	81	78	100	310

Iron Sulphate Spray vs. No Spray

Cane: In this co-operative test with the Experiment Station, average cane yields show a gain of almost 11 tons per acre for the plots which received the iron sulphate spray treatment when the cane was 3 months old. Five out of 7 plot-to-plot comparisons confirmed the average results, although, according to Student's methods, the data were not significant.

Q. R.: Identical average quality ratio results were secured. Plot-to-plot comparisons about broke even.

Sugar: The average gain in sugar yields for the treated plots was 1 ton per acre. This 14 per cent gain was substantiated in 5 out of 7 plot-to-plot comparisons.

Summary: This is the first experiment to be harvested in which chlorotic cane was treated with a 5 per cent solution of iron sulphate when the cane was 3 months old, applied at the rate of about 18 pounds per acre. If the results of this experiment can be duplicated in practice, it appears that iron sulphate can be sprayed on cane having coral soil type of chlorosis, with considerable profit. As these are the first results along this line, the experiment should be repeated.

Evaluation of Yield Equations

By Y. Kutsunai and E. L. Caum

In the article "The Yield Equation and Its Application to Sugar Cane Agriculture," appearing in the *Record* for January, 1928, the method of evaluating yield equations was omitted for the sake of simplicity. In this supplement a few numerical examples are worked to bring out the details of the process of computation.

Spillman's yield equation is: $Y = M - AR^x$, in which

Y = yield of cane in tons per acre.
M = the theoretical maximum cane yield due to natural soil fertility plus an unlimited amount of fertilizer.
A = the theoretical maximum cane yield due to an unlimited amount of fertilizer only, the natural soil fertility not being considered.
R = the ratio between successive increments in cane tonnage due to the progressive increase in amount of fertilizer.
X = number of lots of fertilizer applied;

or, to extend: the yield of cane is equivalent to the ratio between successive increments in tonnage due to fertilizer raised to the power of the number of lots of fertilizer, multiplied by the maximum yield of cane due to fertilizer alone, and subtracted from the theoretical maximum yield possible.

Formula (2a)* is $\log (Y_{x+1} - Y_x) = \log Z = X \log R + \log A\ (1-R)$.

The harvesting data of Lihue Plantation Company, Experiment 5, 1924 crop, are:

Pounds Nitrogen per acre	Nitrogen in lots of 75 lbs.	Actual tons cane per acre	Increments tons cane
0	0	27.31	12.46
75	1	39.77	8.11
150	2	47.88	5.01
225	3	52.89	....

The fertilizer is increased by one lot of 75 pounds of nitrogen per acre for each successive step and the increments in cane weight are all positive. The formula (2a) is applicable in this case.

$$\begin{array}{lll}
\log 12.46 = 1.0955180 & = 0 \log R + \log A\ (1-R) \\
\log \ \ 8.11 = 0.9090209 & = 1 \log R + \log A\ (1-R) \\
\log \ \ 5.01 = 0.6998377 & = 2 \log R + \log A\ (1-R) \\
\hline
\text{Total} \ldots\ldots\ 2.7043766 & = 3 \log R + 3 \log A\ (1-R)
\end{array}$$

This is the normal equation for $\log A\ (1-R)$

$$\begin{array}{ll}
1.0955180 \times 0 = 0 & = 0^2 \log R + 0 \log A\ (1-R) \\
0.9090209 \times 1 = 0.9090209 & = 1^2 \log R + 1 \log A\ (1-R) \\
0.6998377 \times 2 = 1.3996754 & = 2^2 \log R + 2 \log A\ (1-R) \\
\hline
\text{Total} \ldots\ldots\ 2.3086963 & = 5 \ \log R + 3 \log A\ (1-R)
\end{array}$$

* The use of these formulae is explained in the *Record* for January, 1928, p. 77.

This is the normal equation for $X \log R$. The two normal equations are solved for $\log R$ and $\log A\ (1—R)$ by elimination.

$$
\begin{array}{rl}
 & 2.7043766 = 3 \log R + 3 \log A\ (1-R) \\
\text{By subtracting} & 2.3086963 = 5 \log R + 3 \log A\ (1-R) \\
\hline
 & 0.3956803 = -\ 2 \log R
\end{array}
$$

$$\log R = -\ 0.1978402$$

By adding 1 and subtracting 1

$$
\begin{aligned}
\log R &= 1. - 0.1978402 - 1 \\
\log R &= 0.8021598 - 1 \\
R &= 0.6341
\end{aligned}
$$

Substituting the value of $\log R$, which is -0.1978402, in one of the normal equations:

$$
\begin{aligned}
2.7043766 &= 3 \times (-0.1978402) + 3 \log A\ (1-R) \\
&= -0.5935206 + 3 \log A\ (1-R) \\
3.2978972 &= 3 \log A\ (1-R) \\
\log A\ (1-R) &= 1.0992991 \\
A\ (1-R) &= 12.569 \\
\text{But } 1 - R &= 1 - 0.6341 \\
&= 0.3659 \\
A &= \frac{12.569}{0.3659} \\
&= 34.351
\end{aligned}
$$

Formula (2b) is $M = \dfrac{1}{n} (\Sigma\ Y + \Sigma\ AR^{x})$

X	Y	AR^{x}
0	27.31	$34.351\ (0.6341)^{0} = 34.351$
1	39.77	$34.351\ (0.6341)^{1} = 21.782$
2	47.88	$34.351\ (0.6341)^{2} = 13.838$
3	52.89	$34.351\ (0.6341)^{3} = 8.758$
	$\Sigma\ Y = 167.85$	$\Sigma\ AR^{x} = 78.729$

$$
\begin{aligned}
M &= \frac{1}{4} (167.85 + 78.729) \\
&= 61.645
\end{aligned}
$$

The yield equation sought is $Y = 61.645 - 34.351\ (0.6341)^{x}$, in which Y is the cane yield in tons per acre and X is the number of lots of fertilizer of 75 pounds of nitrogen per acre each.

The above method is not applicable when the fertilizer is not increased in steps of one lot each or when the increments in cane tonnage are not always positive. Formulae (3a) and (3b) are used in irregular cases of this nature.

Formula (3a) is $A_1 = \dfrac{\Sigma(Y)\Sigma(R^{x}) - N\Sigma(YR^{x})}{N\Sigma(R^{2x}) - (\Sigma R^{x})^2}$

and (3b) is $A_2 = \dfrac{N\Sigma(YXR^{x}) - \Sigma(Y)\Sigma(XR^{x})}{\Sigma(R^{x})\Sigma(XR^{x}) - N\Sigma(XR^{2x})}$

The data from Maui Agricultural Company, Experiment 5, 1922 crop, variety H 109, are:

Pounds nitrogen per acre	Difference in nitrogen	Actual tons cane per acre	Increments tons per acre
0	75	33.2	+ 10.8
75	50	44.0	+ 4.8
125	50	48.8	+ 4.4
175	50	53.2	— 0.9
225	....	52.3	....

In this experiment nitrogen was increased at first by 75 pounds and thereafter by 50 pounds. This irregularity in the fertilizer application necessitates the use of formulae (3a) and (3b). Not all the increments in cane weights are positive and this fact also calls for the formulae (3a) and (3b). Taking one lot of fertilizer as 25 pounds of nitrogen, which is the greatest common factor of the differences in nitrogen application, the data are rearranged as follows:

Number of lots of nitrogen	Actual tons cane per acre	Increments tons per acre
0	33.2	+ 10.8
3	44.0	+ 4.8
5	48.8	+ 4.4
7	53.2	— 0.9
9	52.3	....

A_1 and A_2 are computed with the assumed value of R. A and R are the correct ones to choose when A_1 and A_2 become equal or very nearly so for a certain assumed value of R. When such a value of R is not readily found, A_1 and A_2 are plotted as in the illustration, and at the intersection of the A_1 and A_2 lines, the values of A and R are read off the chart.

The computation is systematized as in the following table to avoid errors.

Assumed $R = 0.78$

X	Y	R^x	YR^x	XR^x	YXR^x	R^{2x}	XR^{2x}
0	33.2	1.000000	33.200000	0.000000	0.000000	1.000000	0.000000
3	44.0	.474552	20.880288	1.423656	62.640864	.225200	.675599
5	48.8	.288717	14.089390	1.443587	70.447046	.083358	.416789
7	53.2	.175656	9.344899	1.229590	65.414188	.030855	.215984
9	52.3	.106869	5.589487	.961820	50.303186	.011421	.102789
Σ	231.5	2.045794	83.104064	5.058653	248.805284	1.350834	1.411161

$n = 5$

$$A_1 = \frac{\Sigma Y \Sigma R^x - n\Sigma(YR^x)}{n\Sigma(R^{2x}) - (\Sigma R^x)^2} = \frac{231.5 \times 2.045794 - 5 \times 83.104064}{5 \times 1.350834 - (2.045794)^2}$$

$$= \frac{473.601311 - 415.52032}{6.754170 - 4.18527}$$

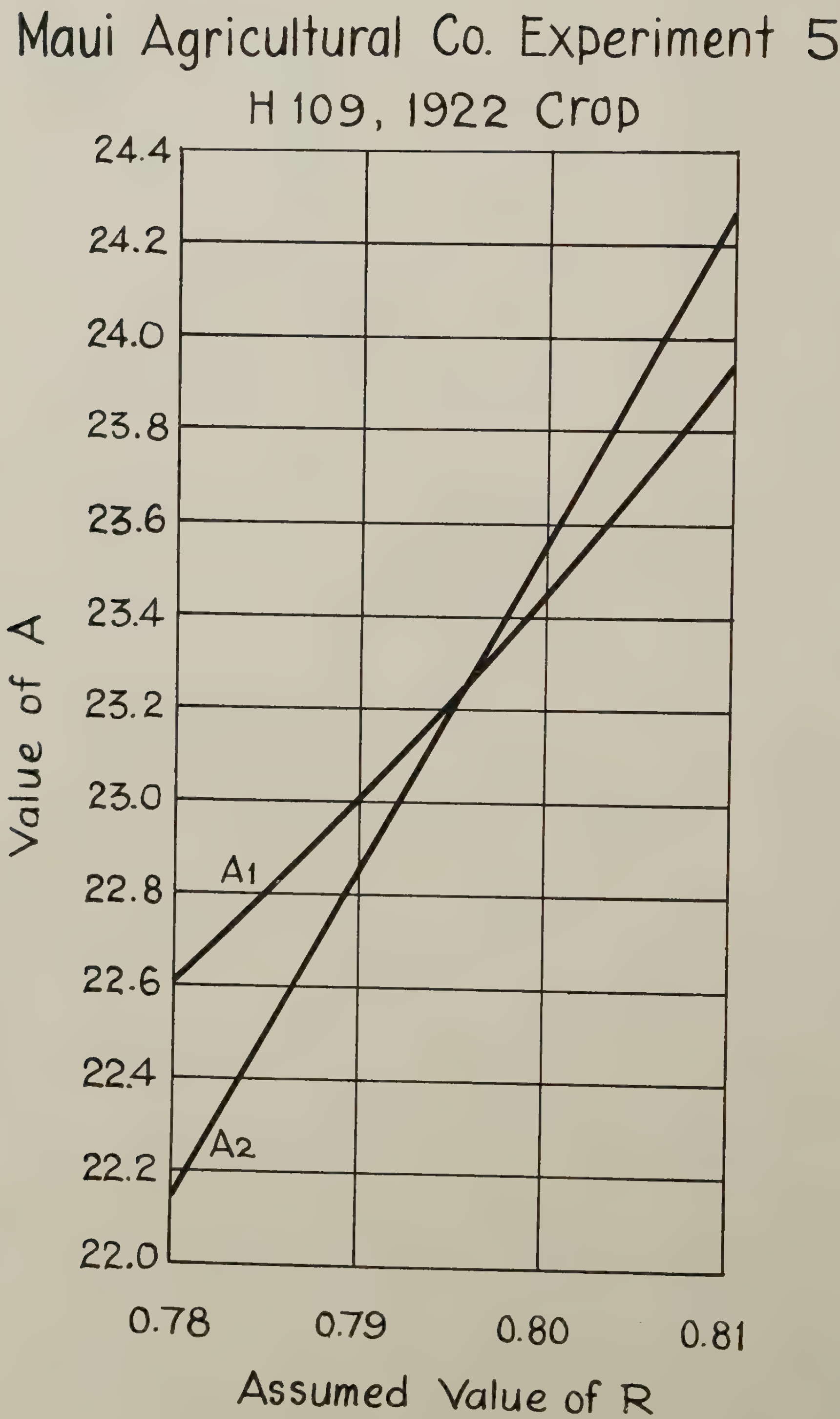
$$= \frac{58.080991}{2.568897} = 22.609$$

$$A_2 = \frac{n\Sigma(YXR^x) - \Sigma Y\Sigma(XR^x)}{\Sigma R^x \Sigma(XR^x) - n\Sigma(XR^{2x})} = \frac{5 \times 248.805284 - 231.5 \times 5.058653}{2.045794 \times 5.058653 - 5 \times 1.411161}$$

$$= \frac{1244.02642 - 1171.078170}{10.348962 - 7.055805}$$

$$= \frac{72.948250}{3.293157} = 22.151$$

Difference, $A_1 - A_2 = 0.458$


Maui Agricultural Co. Experiment 5
H 109, 1922 Crop
24.4
24.2
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
22.4
22.2
22.0
Value of A
A1
A2
0.78
0.79
0.80
0.81
Assumed Value of R

A_1 and A_2 worked out with the various arbitrary values of R are:

Assumed R	A_1	A_2	$A_1 - A_2$
0.78	22.609	22.151	+ 0.458
0.79	23.008	22.846	+ 0.162
0.80	23.450	23.553	— 0.104
0.81	23.941	24.277	— 0.336

Between $R = 0.79$ and 0.80, the difference A_1 and A_2 passes the zero point. By plotting these values, it is seen that when $R = 0.796$, both A_1 and A_2 are equal to 23.25, hence the values sought are:

$$R = 0.796$$
$$A = 23.25$$

M is found by formula (2b)

X	Y	AR^x
0	33.2	$23.25\ (0.796)^0 = 23.25$
3	44.0	$23.25\ (0.796)^3 = 11.73$
5	48.8	$23.25\ (0.796)^5 = 7.43$
7	53.2	$23.25\ (0.796)^7 = 4.71$
9	52.3	$23.25\ (0.796)^9 = 2.98$
	$\Sigma Y = 231.5$	$\Sigma AR^x = 50.10$

$$M = \frac{1}{5}(231.5 + 50.10)$$
$$= 56.32$$

The yield equation sought is $Y = 56.32 - 23.25\ (0.796)^x$ in which Y is the cane tonnage per acre and X is the number of lots of 25 pounds of nitrogen each per acre.

The tables of values, to six decimal places, of R^x, XR^x, R^{2x}, and XR^{2x}, for R from .01 to .99 and X from 0 to 20, are ready for distribution. The tables will be sent on request to the Experiment Station, H. S. P. A.

Formula (5), which is $Y = M - \frac{A}{R^d}\ (R)^x$ is used in the cases where shifting of the zero point is necessary, as, for instance, when the first amount considered is not at the natural zero point, as in the case below.

The harvesting results of Pioneer Mill Company, Experiment 16, 1927 crop, are:

Pounds nitrogen per acre	Tons cane per acre
140	61.4
190	65.2
240	68.7
290	70.4

The common difference in fertilizer is 50 pounds per acre of nitrogen, which is taken as one lot, and if the initial amount of 140 pounds nitrogen is assumed to be the zero point, or no fertilizer, then the data become

Number of lots of nitrogen	Tons cane per acre	Increment tons per acre
0	61.4	+ 3.8
1	65.2	+ 3.5
2	68.7	+ 1.7
3	70.4	....

The yield equation obtained from these rearranged data by the formulae (2a) and (2b) is

$$Y = 74.134 - 12.767\ (0.66886)^{X}$$

The origin of this equation, however, must be shifted back to the natural no-fertilizer point. This is done by the use of formula (5) in which the distance $d = \frac{140}{50}$

Hence the true equation sought is

$$\begin{aligned} Y &= 74.134 - \frac{12.767}{0.66886^{\frac{140}{50}}}\ (0.66886)^{X} \\ &= 74.134 - 39.369\ (0.66886)^{X} \end{aligned}$$

in which Y is cane tonnage per acre and X is the number of lots of 50 pounds per acre of nitrogen.

It is almost needless to add that the harvesting data which are to be subjected to mathematical analysis must be fairly free from error; and that if the form of the curve traced by the harvesting data does not fit the yield equation of Spillman, then some other empirical formula must be chosen. Fundamentally, any mathematical formula that faithfully traces the relation between the yield and the growth factor, such as fertilizer or water, is applicable.

The Use of Yield Equations in Deciding the Proper Proportion of Plant Food to Apply

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By Y. Kutsunai

It is often very difficult to work out satisfactorily the proper proportion of the major plant foods—nitrogen, phosphoric acid, and potash—to apply to the cane crop. Soil analyses, cane juice analyses, and the results of plant food tests have been used extensively as guides in arriving at the decision.

Additional assistance is found in the yield equations evaluated from the results obtained by applying varying amounts of plant foods. The number of equations needed corresponds to the number of the plant foods to be proportioned. For instance, if nitrogen, phosphoric acid, and potash are to be decided upon, then the yield equations on these three elements are needed. The three equations are plotted and the amount of each element needed to produce a given tonnage of cane is read off; or if greater accuracy is desired, computation may be resorted to.

A numerical example is worked out to clarify the above brief statement. In Field 45, Oahu Sugar Company, experiments were run with varying amounts of

nitrogen, phosphoric acid, and potash. Unfortunately, a different variety was used in each experiment, but for the purpose of illustration, the variety difference is ignored. The data follow:

Experiment 3, 1922 Crop, nitrogen test:

Pounds per acre			Cane obtained
N	P_2O_5	K_2O	Tons per acre
0	150	50	27.3
75	"	"	36.2
150	"	"	42.7
225	"	"	46.9
300	"	"	44.6
375	"	"	46.3

The yield equation obtained from the data is $Y = 46.99 - 20\ (0.48)^x$ in which X is in lots of 75 pounds of nitrogen. The amount of nitrogen necessary to produce a given tonnage of cane under the condition of the test is:

Tons cane per acre	Pounds N per acre
30	17
35	52
40	107
45	235

Experiment 4, 1922 Crop, phosphoric acid test:

Pounds per acre			Cane obtained
N	P_2O_5	K_2O	Tons per acre
175	60	50	37.8
"	90	"	40.3
"	120	"	41.5
"	150	"	44.5
"	180	"	44.2

The yield equation obtained from these data is $Y = 47.90 - 18\ (0.75)^x$, in which X is expressed in lots of 30 pounds per acre of P_2O_5. Calculated amounts of phosphoric acid needed for a given tonnage of the crop are:

Tons cane per acre	Pounds P_2O_5 per acre
30	1
35	35
40	86
45	190

Experiment 8, 1922 Crop, potash test:

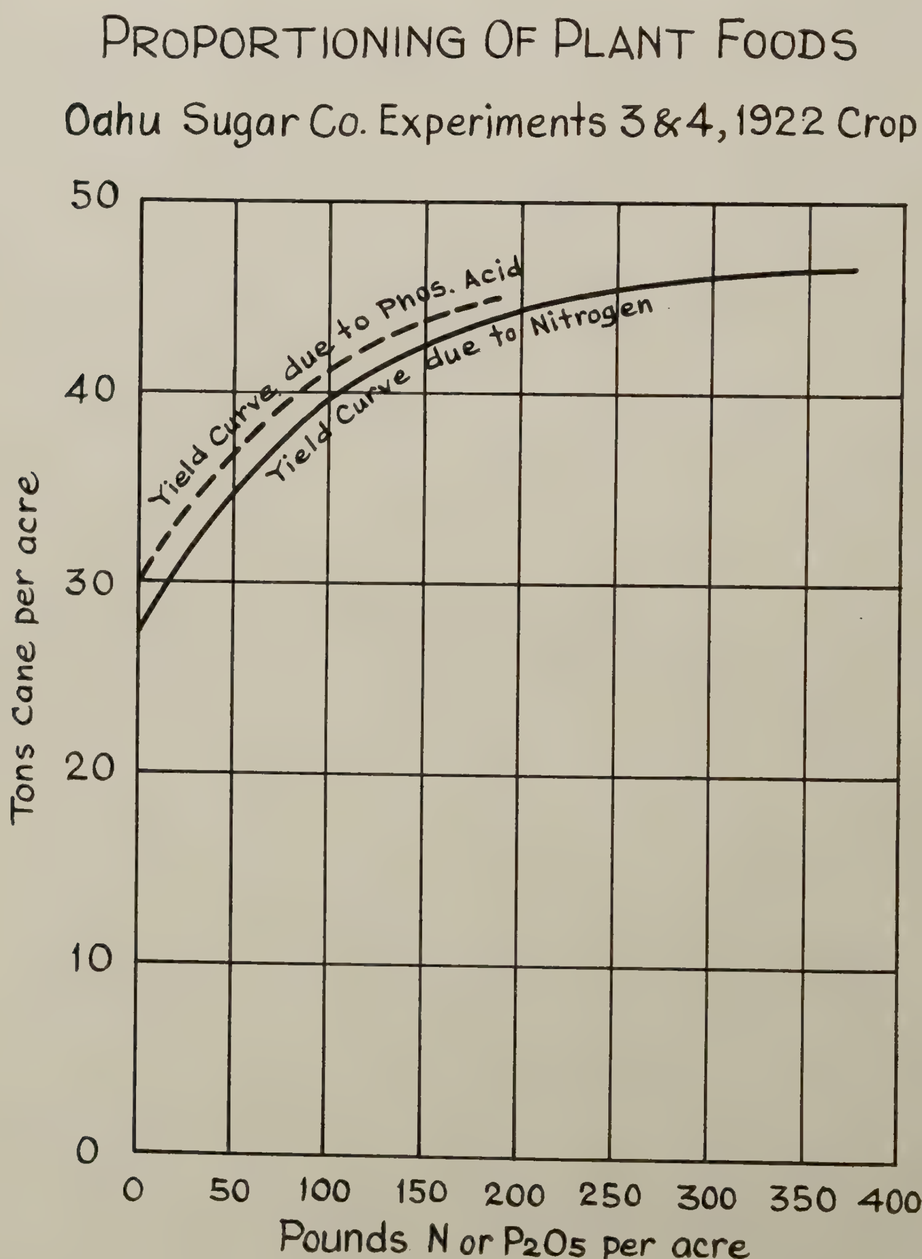
Pounds per acre			Cane obtained
N	P_2O_5	K_2O	Tons per acre
175	120	0	45.8
"	"	100	44.2

The field is evidently rich in potash, hence the question of potash is dropped from further consideration. The other elements required are:

Tons cane per acre	Pounds per acre N	Pounds per acre P_2O_5	Difference $N - P_2O_5$	Ratio $N : P_2O_5$
30	17	1	+ 16	1 : 0.06
35	52	35	+ 17	1 : 0.67
40	107	86	+ 21	1 : 0.80
45	235	190	+ 45	1 : 0.81

The ratio between weights of nitrogen and phosphoric acid necessary to produce a crop varying from 30 to 45 tons per acre is not constant, which fact is not in accord with the accepted view that plant foods in general are demanded by the cane crop in the same proportion, whatever the size of the crop will be.

In this particular field, it seems to be a good practice to apply a little more phosphoric acid than the indicated amount, perhaps equal amounts of nitrogen and phosphoric acid, since the latter does not easily leach out, is cheaper than the



former, and does not affect cane ratio unfavorably. The total amount of the two elements to apply depends on the size of the crop desired.

It is questionable, however, whether or not the size of the crop produced by a given amount of nitrogen with a large excess of phosphoric acid (that is, when nitrogen is the limiting factor), will be the same even when phosphoric acid is also decreased to almost the limiting amount. No experimental data are available at present to answer this question. It is hoped, however, that a series of tests will be run in the near future to clear this point.

Corn Root Rot—A Soil-Borne Disease

A paper under the above title by Valleau, Karraker, and Johnson, in the *Journal of Agricultural Research,* Vol. 33, 1926, contributed from the Kentucky Agricultural Experiment Station, makes reference to Hawaiian investigations on root rot of sugar cane as follows:

A review of the literature on this type of root injury revealed the striking similarity between the sugar-cane root rot described by Carpenter and the root rot of corn produced in either sand or soil pot cultures by the use of either diseased soil or diseased roots. The hyphae and the oospores in diseased roots of corn are strikingly similar in appearance to those pictured by Carpenter, and the similarity suggests a relationship between the two fungi. In a later paper Carpenter showed the morphological similarity of his Pythiumlike fungus to *Pythium Butleri* Subramaniam and *Rheosporangium Aphanodermatus* Edson. Subramaniam, as quoted by Carpenter, found his organism to be parasitic on *Nicotiana tabacum, Zingiber officinale,* and *Carica papaya.* In the present studies the writers have found that rotted corn roots produced a rot of tobacco similar in character to the disease produced on corn roots in pot cultures. Although it is too early to draw definite conclusions in regard to the actual cause of corn root rot, there is a strong suggestion that the Hawaiian root troubles and those of corn in the United States may be very similar in nature. The fact that the writers have not obtained a Pythiumlike organism in isolations from rotting roots is not surprising, as Carpenter had considerable difficulty in isolating the organism until a favorable medium was discovered. In 1919, Clinton (Conn. Agr. Exp. Sta. Bull. 222) obtained plants of corn severely affected with root rot, and found, in the pith of the stubble in the vicinity of the nodes, the oospores of a fungus which he identified as *Phytophthora cactorum,* but he was not certain whether it was a Pythium or a Phytophthora. The oospore measurements and appearance of the spores correspond closely with those illustrated in this paper.

Free-hand sections of rotting corn roots grown in infected soil, or in sand cultures inoculated with rotten corn roots, have consistently revealed a large-diameter, generally non-septate organism, and numerous oospores of the Pythium type. The type of injury produced in soil and sand cultures is remarkably similar to the injury to Lahaina cane grown in sick soil and caused by a Pythiumlike fungus. The suggestion is made that corn root rot, other than seedling blights known to be caused by certain seed-borne organisms, is caused by a fungus similar to the fungus causing the cane root rot.

Rooted corn roots added to sand cultures of tobacco are capable of causing a type of injury which appears identical with the so-called brown root rot of tobacco in the field.

H. P. A.

Notes on Pythium Root Rot of Sugar Cane

II

By C. W. Carpenter

In the last number of the *Planters' Record** a series of notes was begun on current investigations of root rot of cane being carried on in the department of pathology.

The idea was advanced therein that logically we must consider the universal failure of the Lahaina type of cane as a specific disease distinct in general from the more or less localized growth failures and root failures of our standard canes which for the present we are considering under the growth failure complex as due to a variety or combination of causes. In these latter growth failures the specific cause of Lahaina failure no doubt plays a part. It was considered that the widespread failure of the Lahaina type as a commercial cane could more logically result from a concomitant living cause or a small series of closely related causes than from such a variety or combination of diverse factors.

Seemingly in a class with Lahaina cane so far as root disease is concerned, is the otherwise promising variety E. K. 28, which it is reported is now being replaced in Java with other varieties largely because of its susceptibility to root rot. In Hawaii we have recently noted the utter failure of this variety in one locality as soon as it was planted in the field from the quarantine house. *Pythium aphanidermatum* was the apparent causal factor. This failure of a variety other than Lahaina again indicates the existence of specific root disease, the cause of which we would expect to be a specific living factor of widespread rather than local occurrence.

The Lahaina variety of cane has practically disappeared commercially, but a knowledge of the factors that have brought about its elimination is considered very important, since these same factors may be active now in reducing yields of our standard canes below what they might otherwise be, and possibly their effect is increasing, or is cumulative in nature. However improbable it may appear, we should not overlook the possibility that the conceivable ultimate effect might prove to be somewhat the same as on Lahaina. We therefore continue to investigate the so-called Lahaina root disease in relation to the fundamental problem of root disease of cane in general.

Wherever Lahaina has failed commercially, present standard varieties are resistant to the specific causal factor. Before it was known that *Pythium aphanidermatum* occurred at all on the canes Yellow Caledonia, H 109, and D 1135, in the field, some evidence was obtained experimentally that the resistance of these varieties to this fungus was only relative, not absolute. Later, a few cases of root rot of these varieties were observed in the field, and now we are finding that

* *The Hawaiian Planters' Record*, Vol. XXXII, No. 1, p. 107, 1928.

the occurrence of this fungus in a few rotting roots on these canes is not unusual. In general, so few roots in proportion to the total are injured, that we would not except to note above-ground symptoms. Where definite above-ground symptoms have been observed on these canes, some other factor has appeared more concerned as a primary cause than *Pythium*.

We are, then, concerned with the questions: To what degree are our present commercial varieties affected by root disease? What is the nature of their resistance to *Pythium* and other specific causes of root rot? How permanent is this resistance?

The experimental plantings of Lahaina in the Hilo and Hamakua districts of Hawaii, following twenty to thirty years of successful culture of canes resistant to root diseases, already indicate after a few months' growth that this variety would still be a commercial failure. This demonstrates the persistence of the causal factor. How could it persist except by growth on the cultivated cane either as a saprophyte on already dead tissues or as a parasite on the cane roots in some degree? Possibly it could exist on the roots of an alternate host or grow saprophytically on organic matter in the soil. Whether the resting spores of *Pythium* could remain alive this long can only be conjectured, but the rather frequent observation and isolation of this fungus from the roots of resistant varieties show the probable means of persistence. Whether or not the *Pythium* theory of root rot is of universal application to Lahaina failure, we continue to find this fungus associated with root rot of this cane in Hawaii. We certainly have never found this fungus to be a harmless associate in the interior of healthy roots, though it is true that stools of the resistant canes seldom show marked distress of the aerial portion as a result of the rotting of a few roots by this fungus. It can hardly be considered normal for a plant to lose a varying proportion of its young primary roots as a result of the attacks of *P. aphanidermatum*.

As a working hypothesis we may assume, obviously, that a vigorous and normally watered cane plant can lose a number of roots from time to time without appreciable effect on the above-ground vegetation provided the remaining root absorption area, or dormant root buds in reserve, are sufficient to supply the needs of the stool. We may further assume that normally there is a balance between root absorption area and the size of the above-ground plant, maintained in proportion as the plant grows. Under existing conditions the varieties resistant to root disease then are able to maintain this balance sufficiently well so that the visible portions of the stool remain apparently healthy, while a susceptible variety often finds itself with more stalk and leaves than the reduced absorption area of a crippled root system can maintain in a healthy growing condition. It thrives when the balance is maintained and stops growing with a slight change in balance, i. e., when root area becomes insufficient.

Under this hypothesis certain varieties are resistant as a result of: (1) real resistance of the roots to the entrance of the causal agent of rot; and, (2) more prolific rooting combined with less breaking down of root tissue under attack. Under fluctuating conditions, Lahaina cane sometimes can maintain and sometimes cannot maintain a sufficient root system to balance the rest of the plant growth. This would explain the erratic growth of this cane where it has failed and re-

covered, changing soil conditions in their relation to root extension and root rot having temporarily restored the balance.

Occurrence of Fungi

Fungi other than *Pythium* commonly found present in and about the badly rotted roots are: *Fusarium* species, *Trichoderma* species, *Mucor* species, and several fungi suggesting *Rhizoctonia,* as well as a fungus with conidia in chains resembling *Monilia* or *Spicaria.* Bacteria are omnipresent. Of the above, some of the *Fusaria,* and especially *Rhizoctonia,* may later prove to be important in relation to root rot. The *Mucors* and the *Spicaria* occur rather infrequently. At present the bacteria, most of the *Fusaria, Trichoderma* and *Mucors* appear to be only secondary. Inoculation tests will be necessary to establish their relation to normal roots.

Parasitism of Pythium Species Isolated on Hawaii

Incidental to inspection trips on Hawaii, four *Pythium*-like fungi have been isolated. Of these four, two are *Pythium aphanidermatum,* identical with the *Pythium* previously found parasitic on Lahaina cane roots in inoculation tests. The other two are somewhat different, one forming larger spherical conidia or oogonia, and the other differing in other features.

The two strains tentatively identified as *Pythium aphanidermatum* comprise one from the Lahaina plot at Honokaa, Field No. 6, and one from the plot in Field J-2 at Olaa.

The following table shows the result of inoculation of sterilized Waipio soil with ten strains of *Pythium,* including the above-mentioned four. This inoculation experiment, besides confirming the earlier work on the parasitism of *Pythium* suggests that the strains are somewhat adapted to the soils in which they occur so far as their root parasitism is concerned. One Hawaii strain, No. 36 A 7 A, from Honokaa, proved very destructive to Lahaina cane roots in the sterilized soil from Field E at Waipio, Oahu.

INOCULATION TEST WITH *PYTHIUM* SPECIES

Fungus	Culture No.	Source	Variety	Root Rot ±
P. aphanidermatum	2	Ewa, Field 18B	H 109	+
" "	7	Pathology Plot	E. K. 28	+
" "	9	Waialua, Field 19	H 109	+
" "	10	Maui Agr. Co., Field 87	H 109	+
" "	14	Kailua	Lahaina	+
" "	26B	Waipio, Field E	"	+
" "	36A7A	Honokaa, Field No. 6	"	+
Pythium species	3	Onomea, Field 34	"	—
" "	4	" " "	"	—
" "	$33B_2$	Olaa, Field J-2	"	—

Of those showing negative results, Culture No. 3 does not appear to be *Pythium aphanidermatum.* Culture No. 4 differed from most of the other strains in growing at a lower hydrogen ion concentration in a buffered synthetic medium (pH 4.16).

Possibly this fungus, otherwise not noted to be different from *P. aphanidermatum*, would prove parasitic on a soil similar to the one from which it was collected. Culture No. $33B_2$ also was able to grow on the same medium. It should be noted that the only other of the ten strains growing on the acid medium mentioned was No. $26B_2$ from the nearly neutral soil environment of Waipio, and it was found parasitic.

In the root study boxes of this experiment an observation was made as to the reaction of the roots to the attack of the root rot disease, confirming our supposition regarding the forced development of roots to replace absorption area lost.

We have frequently noticed that stools of Lahaina cane in the presence of the root disease have rather characteristically a set of new white primary roots from the root bands of the lower nodes of the shoots, while it seemed to us that in Lahaina and other canes growing normally, the primary roots, once started, continue to extend, branching into secondaries, tertiaries, etc., and further development of new primaries is rare, possibly not occurring abundantly except as new shoots develop nodes or the cane is ratooned.

In the root study boxes with natural sick soil, as well as in sterilized sick soil which had been subsequently inoculated with *Pythium aphanidermatum*, several crops of these new primaries have grown out, been attacked and destroyed. A crop of new white primaries grew out, remained white and healthy in appearance for several days, reaching a length of three or four inches; after some eight or ten days they showed almost simultaneously the fresh reddish lesions of *Pythium* attack. The roots became more and more yellowish-red to deep red in spotted areas which more or less girdled the root. The next stage was either a softening and final complete collapse to a flaccid condition, or the progress was slower, the color changing to dark red, finally to almost black. The larger primaries often took the former course, while the smaller primaries, secondaries, etc., either developed flaccid tips rather quickly or else remained rather firm if attacked some distance from the tip, the red lesions working through cortex and stele, the color gradually becoming darker to black. Reserve dormant root buds seem to have become exhausted, as extension and root replacement now are by branching of primaries and secondaries, etc.

This successive forced root development, attack, destruction and later replacement has been noticed three times in the present inoculation experiment. To explain this rather simultaneous attack of the whole crop of new primaries, the following seems logical: The roots are attacked by the fungus which is well distributed in the soil soon after they start out from the node or after they reach a definite stage in growth; since the roots start at approximately the same time, the time of infection would be about the same, and with a rather definite incubation period or period of growth in the roots before gross symptoms appear, we would have an apparently simultaneous breaking down of the series of roots.

Notes on Root Rot on the Island of Hawaii

A second and third inspection of the experimental Lahaina plots planted by the Olaa Sugar Company, Ltd., the Honokaa Sugar Company, the Onomea Sugar

Company, and the Pepeekeo Sugar Company, in cooperation with the Experiment Station, was made November 8 to 14, 1927, and January 17 to 21, 1928, respectively.

In general, it may be said that in November the Lahaina was growing more vigorously in all plots than in August. In no case was there a complete failure to grow accompanied by the drying leaves and death of the plants that we have observed with this variety when diseased on Oahu. The plants were green, generally characterized by unevenness in size, and in no case as large and healthy in appearance as a whole as the adjoining canes of other varieties. Individual stools in all plots might have been chosen which would compare favorably in size with resistant commercial canes near by.

Typical rotting of the roots of the *Pythium* type was present in all plots and the fungus *Pythium* was observed microscopically in such roots collected from all the plots. Again both smooth- and rough-walled oospores of *Pythium* type were noted; sometimes one form and sometimes the other predominated. The rough-walled oospores have not developed in pure cultures and their significance is not determined.

The time elapsing between collection of root material on Hawaii and the necessary isolation work when done in Honolulu made it desirable to attempt isolations at Hilo. In this way pure cultures of *Pythium* species were secured from the Lahaina roots at Honokaa, Olaa and Onomea. A considerable collection of other fungi and bacteria was also secured for study.

Normal growth of Lahaina was not found in any of the plots as a whole in January. In portions of the plots, particularly in Field 34 of Onomea plantation in the higher places, and Honokaa plantation, Field 29, in scattered small areas, growth of stools might be considered fair, considering the factors of elevation and time of year. In these mentioned areas stooling was good and fair-sized canes were common. At Pepeekeo Sugar Company, Field 1, somewhat the same conditions were present, here and there nearly normal growth having taken place. It should be remarked, however, that even in these exceptional areas, where possibly normal sized canes had developed, the root systems of stools examined were not strikingly better than those of the near-by small stools. More roots were represented on the large stools and there was a stimulated mat of small feeding roots close to the stool and restricted to a few inches of the surface soil. The poorer stools showed less of this forced root growth, but in general as to root rot of roots present there was not the contrast in root system we would expect. All were uniformly deficient in healthy appearing roots. The typical reddish, softened roots of the *Pythium* type of root rot were present in every case, in greater or less numbers.

It is remarkable that some of these stools have made the growth of cane that they have with the scant root system. It does not seem probable that they can continue to grow unless at times they are able to maintain more roots than we observed. With the slight attachment to the soil, as they become heavier, little wind would be required to uproot them.

In the mauka fields at Olaa, Honokaa and Onomea, we found smaller stools, as would be expected at the higher elevation. At Olaa, Field W, the cane did

not have the dry appearance of the plot in Field J-2. In the center of the area, in a flat place, the stools were closing up, and perhaps normal growth for Lahaina in that locality was approached. Other parts of the plot were decidedly poor, with weak, scattered stools common. Except for the central area, the growth has been poor. There was little change from the time of the November inspection in either of the plots at Olaa.

The lower plot, Field J-2, elevation about 300 feet, still presents the appearance we associate with deficient moisture and insufficient nitrogen, although it had received an unusual amount of rain, even for Olaa. The leaves are pale to yellowish green and rather dried out. Stooling is weak and few stools have any sizable canes yet. The adjoining Yellow Caledonia is growing well in contrast to the Lahaina, which appears to be standing still, a typical example of Lahaina failure.

Manager A. J. Watt raises the question, whether Yellow Bamboo, and later Rose Bamboo, which failed in much the same way as Lahaina, failed from the same cause. They first grew well with two ratoons possible, later with one ratoon, and finally even the plant crop failed completely, like Lahaina.

Notes on the individual plots, with representative photographs, are recorded below.

OLAA SUGAR COMPANY

Plot in Field J-2, Area 1/20th acre.
Planted, May 20th, 1927.
Elevation, about 300 feet.

In November as well as in January, the Lahaina cane in this plot more nearly resembled Lahaina diseased cane as we know it on Oahu, than in any other plot of our series. The stand was of varying sized plants, pale yellow-green in color and of a general unhealthy appearance without strikingly definite symptoms. It was in general only about half the size of the adjoining Yellow Caledonia (the latter is a few weeks older).

Mr. Watt observed that it has the typical appearance of the old type of Lahaina diseased cane. The accompanying photograph, taken November 13, shows the general appearance and size of the Lahaina cane in this plot. (Fig. 1.)

The roots: A medium sized stool was removed and washed. It had a decidedly poor root system. Only one or two healthy roots were found. A fair development of root-band roots had formed, together with a considerable mass of fibrous branches, but all were rotting badly.

A larger stool, which had several nodes, had developed a fairly large root system, now represented by soft, reddened to blackish roots. In fact, in the surface layers of this shallow soil, we found rather more roots represented than the plant would normally be expected to require if the roots all extended normally and functioned. It was apparent that a forced development has occurred in response to the death of the root tips. Neither of the plants examined had any normal primary roots and but few have been developed.

Microscopically: It was noted that the rough-walled oospores previously mentioned were abundant in this material. The smooth-walled oospores of *Pythium*

Fig. 1. Lahaina in Field J-2 at Olaa, six months old. Slightly older Yellow Caledonia at left and in background. This is a characteristic phase of Lahaina failure, according to Mr. A. J. Watt.

aphanidermatum were likewise present. Several pure cultures of *Pythium* were isolated from these rotting roots.

In January, all roots were badly rotted with the *Pythium* type of root rot, except a few new primary roots three or four inches long.

Field W, Sec. "B", Mountain View. Area 1/20th acre.
Planted, May 20th, 1927.
Elevation, 1,000 feet.

This plot is in a shallow soil over stones. In November the surrounding D 1135 was rather uneven and spotty. Compared with this, the Lahaina was not so bad. The Lahaina was of uneven sizes, rather pale and yellowish even for this variety, and many plants were much stunted, some almost dead. Quite a number of plants, however, compared favorably with the near-by D 1135.

One of the better plants removed in November had developed a considerable root system. The short new node roots were often healthy in appearance, but the deeper ranging roots were all soft at the tips, i. e., flaccid. Some of the younger primary roots, which had ranged straight down three or four inches, had a reddened to yellowish translucent appearance previously described in the first report on the plot in Field 33 at Onomea. This is the characteristic appearance of *Pythium* actively attacking the large primary roots near and at the tip, and precedes a breaking down into a soft mass or empty skin.

On a smaller plant the band roots of the seed had developed abundantly with much branching. They appeared to be supplying the plant with its moisture and

nutrients, for the primary roots of the shoot were all reddish-yellow, and breaking down with decay. Judging by the remains, they have rotted off about as fast as formed. Besides several rotted stubs of primary roots from the shoot, there were counted six red to yellow affected roots from the shoot, with two additional, which were of healthy appearance. A stunted D 1135 stool near by showed a few red lesions on the roots, but none definitely of the *Pythium* type.

Microscopically: *Pythium aphanidermatum* was observed to be present.

In January, scarcely a living root could be found on the larger stools in the flat area near the center of the plot. All were rotting with the typical appearance of *Pythium* root rot. Pure cultures of *Pythium* have now been isolated from large, young, primary roots a few inches long and just showing the red coloration of the early stage of *Pythium* destruction.

Honokaa Sugar Company

Field No. 29. Area about ½ acre.
Planted, April 18th, 1927.
Elevation, about 500 feet.

The Lahaina in this plot at Honokaa, Field 29, had improved considerably by November. The plants were still of varying sizes, but all green in general, except such dry lower leaves as were probably due to a rather dry soil. Some stools, however, seemed rather physiologically dry than of the dry appearance we associate with dry soil, i. e., marginal drying and death of tissues at edges of older leaves. By physiologically dry is meant the dryness and lack of normal turgor throughout the whole plant, without death of marginal leaf tissues. Many of the larger plants compared favorably with near-by varieties.

The root systems: One of the larger plants had an extensive root system with possibly a normal amount of fibrous roots. A smaller plant had a restricted root development with few fibrous roots in proportion to the size of the plant. The stele of all the primaries was rotted off at a distance of one foot or less from the stool base.

Considering the appearance of this cane in August with the slow start of many seed pieces at that time, it was evident in November in the dry soils existing that this cane was growing and maintaining about 50 per cent of the growth of adjoining canes. The larger plants were over 6 feet tall.

Microscopically: Both smooth- and rough-walled *Pythium* oospores were seen in quantity in the softened stele of affected roots.

The roots of a small stool as well as those of a portion of a large stool were washed out and examined January 20, 1928. A fair root system was present on both. Some *Pythium* rotted roots were found and these later showed the characteristic features of the fungus when examined with the microscope.

Honokaa Field No. 6. Area about ½ acre.
Planted, April 18th, 1927. (Replanted later.)
Elevation, about 1,250 feet.

In November the Lahaina had become better established and both small and large plants had in general grown at a rate comparing rather favorably, consider-

ing the elevation, with the near-by D 1135. With two series of plantings of the Lahaina and an uneven scattered stand, with some plants just getting a start, it was difficult to judge how much of the observed above-ground effect had resulted from the very evident root rot present. This estimation was further complicated by the very uneven, patchy growth of the D 1135 near by.

In both plots at Honokaa it was very evident that some factor was more active on the Lahaina than on the other varieties near by. But in the plot in Field 6, there was not the sharp contrast noted in some of our other plots, not necessarily because the Lahaina was doing so much better than in other localities, but the near-by varieties for comparison were not so strikingly more vigorous than the Lahaina. The largest Lahaina plants were about 3 feet high.

One of the larger plants appeared to have sufficient functioning roots. Root rot was evidenced by the number of short primaries, shrivelled at the tip as if previously flaccid, now dried out and shrunken. The soil was rather dry. This plant appeared to have kept ahead of the root rot by producing roots in the relatively dry soil faster than they were destroyed.

Pythium root rot, though present in both plots at Honokaa, was not very active at the time of observation, possibly owing to rather dry soils; at least not active enough to cause entire loss of roots and drying leaves.

Microscopically: Very numerous rough-walled oospores of the *Pythium* type were noted. A *Pythium* fungus was isolated at Hilo from this material.

In January, it was noted that the roots of the Lahaina in this plot were mostly in the surface soil. But few of them were healthy in appearance. Abundant oospores of *Pythium* were later found in the roots collected.

ONOMEA SUGAR COMPANY

Field 33. Area, about 1/20th acre.
Planted, May 17th, 1927.
Elevation, about 1,200 feet.

The Lahaina cane in this plot was in November in decided contrast in size with the adjoining Yellow Caledonia and the D 1135 across the road. It had a nearly normal green color, however, and the larger plants were stooling and forming joints. Considerable variation in size persists, with many small, weak plants. The larger plants were about 3 feet high.

Here again we saw the correlation between size of plants and healthy and absorbing area of the roots. The larger plants had a few more healthy roots in proportion to rotting root area than the smaller plants. We found in plants of both sizes comparatively few really healthy appearing roots.

The new primaries from the stalk root bands were mostly softened or yellowish-red, translucent to watery in appearance, with only a few of the most recently formed that were normal white in color. Such roots as developed to some length before being attacked were softened to flaccid at the tips, with forced branching. In removing the plants no implements were needed. It seemed that only one or two live roots had to be snapped to pull out the stool. The soil was wet.

Microscopically: While the smooth-walled oospores of *Pythium aphanidermatum* predominated, nevertheless there were a considerable number of the rough-

walled *Pythium* type in association in the rotting tips. The swollen mycelium and prosporangia were also observed.

It was observed in January that the root systems of both large and small stools were badly rotted with *Pythium* root rot. Very few roots on a smaller stool appeared at all healthy. A larger stool had now a fair set of new roots about three inches long, white, and for the most part, healthy; some were already in the first stages of breaking down by *Pythium,* characterized by reddening and girdling. The previous crop of roots as well as some of this set were often but empty sacs or skins or else very flaccid. There were a few fibrous small roots on the larger plant. The fungus *Pythium* was isolated in pure culture.

Field 34. Area, about 1/10th acre.
Planted, May 14th, 1927.
Elevation, about 400 feet.

In November the Lahaina had made considerable growth since the previous inspection in August, but it was still rather uneven in size. It was likewise in marked contrast in size with the adjoining Yellow Caledonia, though the largest and most vigorous Lahaina in any of our plots. Both varieties were rather large, and it was found impracticable to try to show the difference with photographs, since in the Lahaina, scattered plants of the larger sort interfered with the view.

The stools removed showed the same type of diseased-reddened to yellowish roots as in Field 33. The difference was in the number of roots rather than in the relative degree of health. The larger plants had in proportion more roots either healthy or only partially broken down than the smaller plants.

One of the larger plants was removed, the roots washed out and taken to Hilo for photographing. The photograph shows a few healthy new white primaries and a great number that should be white but are reddened. On close inspection these show in the photograph as grayish mottled roots or quite black. On this sized stool the whole root system washed clean should be nearly white, the older roots being somewhat darker, to brown. (Fig. 2.)

Microscopically: The root tips and reddened areas showed plentiful mycelium of *Pythium. P. aphanidermatum* was isolated at Hilo.

By January this cane had grown considerably. Portions on high ground had stools nearly as large as the Yellow Caledonia near by. In the center of the plot, a few feet lower, were smaller and poorer stools with little or no stick.

The smaller stools in the lower ground had very poor root systems, most of the roots being rotted off by *Pythium.*

The larger cane, on somewhat higher ground, was quite healthy in appearance and had 10 to 12 joints, the canes being about 1¼ inches in diameter. There was a dense mat of forced development of fibrous roots close to the stools and in the surface layers of soil. There were very few roots below a depth of about six inches. The larger roots were rotted off by *Pythium* and the steles of such roots were soft and red from the same fungus. They broke off very easily.

The fungus *Pythium* was readily found in this material.

Fig. 2. Roots of a Lahaina stool six months old, Field 34, Onomea Sugar Company. At this age all the roots should appear almost white when washed clean. The gray-spotted, mottled and dark-colored appearing roots are in reality various reddened stages of *Pythium* root rot. Even the large white primaries show small red lesions.

PEPEEKEO SUGAR COMPANY

Field 1. Area, about 1 acre.
Elevation, about 100 feet.

In November, this cane was growing fairly well but irregularly, as in all the other plots. It was decidedly smaller in general than the adjoining Yellow Caledonia.

One of the larger plants of the plot was removed and the roots washed out. It had developed a large root system with a considerable mass of fibrous roots. Most of the large, short, young primaries, and the longer ones also, were breaking down badly with *Pythium* rot. Often the young primaries, 3 to 5 inches long, were just empty skins with the interior completely broken down. Others, not so

far gone, were yellowish to red, and water-soaked in appearance. The soil was moist, and Manager Webster reported a heavy rain two nights before our inspection.

This plant appears to have been growing vigorously, but the extensive root system formed had been recently attacked throughout. Above ground, the plants appeared quite healthy, green and fresh, stooling considerably, but below ground they were very unhealthy, since scarcely any absorbing area was functioning.

A smaller plant was also examined. The young roots were mostly rotting, especially at the tips; while the older and longer roots were softened the whole length. Fibrous roots were very few. Reddened cortex roots and softened to completely destroyed steles were characteristic of the root system of this plant.

A photograph was taken to show the uneven growth and contrast in size with the adjoining Yellow Caledonia. (Fig. 3.)

Fig. 3. A corner in the Lahaina plot in Field 1 at Pepeekeo. The Yellow Caledonia in the background is the same age (about six months).

Microscopically: Both the smooth-walled *Pythium* oospores and the rough-walled oospores were observed in large numbers in this material.

In January it was noted that the Lahaina had continued to grow but had not made the showing of the near-by Yellow Caledonia; it was uneven in size, few larger plants approaching at all the size and vigor of the Caledonia.

Both large and small stools had considerable root development, but of this little was healthy. Even the new roots, 5 or 6 inches long, as well as those still shorter, were more or less red rotted with the typical appearance of *Pythium* root disease. Many such young roots were merely empty skins, or sacs of water. Others were

more solid but beginning to be flaccid. Numerous oospores of *Pythium* were readily found in this root material.

Summary of Notes of Inspections of Lahaina Plots on Hawaii

The experimental Lahaina plots of Lahaina cane made in cooperation with the Olaa Sugar Company, Ltd., Honokaa Sugar Company, Onomea Sugar Company, and Pepeekeo Sugar Company, were inspected November 9 to 13, 1927, and January 17 to 21, 1928, for the purpose of making root studies.

In general, the Lahaina had become better established and had a better general appearance than at the time of the first inspection in August. In no case was there a complete collapse of stools with drying up of the plants as we often noted in extreme cases on the island of Oahu. In general, the Lahaina is characterized by uneven-sized plants with no plot as a whole as healthy and vigorous-appearing as the near-by commercial canes.

Typical *Pythium* root rot was very evident in all plots, both in November and January, as soon as the roots were exposed, and the fungus *Pythium aphanidermatum,* or a closely related form at least, was observed with the microscope in diseased roots from all plots. Both smooth- and rough-walled oospores were present.

At Hilo, pure cultures of *Pythium* species were isolated from diseased roots collected at Olaa, Honokaa and Onomea. Several associated organisms of possible significance were isolated for observation.

It is increasingly evident in all of the localities that Lahaina will not succeed commercially after the long period of growth of resistant canes. At Honokaa, under rather dry soil conditions in November, the Lahaina was not so conspicuously in contrast with near-by commercial varieties. However, the root systems were quite heavily infected with *Pythium* root rot and we may anticipate a change with more soil moisture through the winter months.

At Pepeekeo, the Lahaina plants, while uneven in size, appeared to be growing quite vigorously. The large root systems, however, were in an active stage of *Pythium* rot, both in November and January. This underground condition had not yet been reflected in the foliage by definite symptoms of distress.

The management of the plantations concerned in this cooperative root disease study maintain an active interest in these Lahaina plots and are doing everything practicable to give the old favorite variety a fair trial. In some cases they have expressed a keen disappointment in the failure of Lahaina to respond to the modern improved agricultural practices and the resulting improved soil conditions. It is a pleasure to again acknowledge the helpful cooperation extended to us in our root studies.

The Relation Between Soil Treatments and Nematode Attacks to Cane Roots in Central Maui Soils

By Guy R. Stewart, F. Muir, R. H. Van Zwaluwenburg, G. H. Cassidy and Fred Hansson

Previous progress reports from the departments of chemistry and entomology have referred to the growth failure which has occurred in certain small areas of H 109 cane in central Maui. The total acreage of cane land involved in these limited poor spots is comparatively small. Very few of the localities where failure has occurred, exceed one-half acre to two acres in extent. The immediate economic return to be obtained from the improvement of these small tracts of cane land is evidently a minor factor. The points on which we have focussed our attention are, first of all: the question whether this growth failure indicates a decrease in the vitality of the H 109 variety of cane; secondly, is the trouble likely to increase in the fields now affected, or spread to new localities? thirdly, can the poor areas be improved by practical methods of field treatment?

The work of the chemistry department upon this problem has centered upon a study of the chemical character of the soils of typical areas where good cane was growing, contrasted to the soils of the adjacent poor spots. A study of the soluble salts, soil reaction and composition of the displaced soil solutions was carried out by the senior author. The results of this work have shown that the soils of the poor areas were not consistently higher in their content of soluble salts or in alklaline soil reaction than the soils of the adjoining land where good cane was growing. Analyses of the displaced soil solutions showed that the solutions from the good cane soils consistently contained a higher content of potash, but potash salts alone have not been found sufficient to cause a recovery of the H 109 cane growing in the poor spots.

Dr. F. E. Hance made an extended study of the content of replaceable bases in the soils of the good and poor areas. The results of this work have been reported in a previous issue of the *Record* (2). It was found that the soils of the poor areas consistently showed a higher content of replaceable magnesium than was present in the good soils. Laboratory experiments with magnesium salts showed that an excess of this base, combined with the soil in replaceable form, exerted a notably deleterious effect upon tilth, permeability and aeration of the soil, so that cane growth was notably retarded.

F. Muir, R. H. Van Zwaluwenburg and Dr. G. H. Cassidy, of the entomology department, have made extensive studies in the field of the root development of the poor cane contrasted to that of stools of adjoining good H 109 cane. This work has shown that notable root destruction at an early stage of the growth of the cane was associated with this localized growth failure. In many of the poor spots a heavy infestation of *Heterodera radicicola* and *Heterodera schachtii* occurred in the roots of stools in the poor areas. This nematode infestation was

sufficiently intense at times so that it appeared possible that it might be responsible for the greater portion of the root destruction which occurred.

The work of both the chemists and entomologists upon this problem has been carried on in close cooperation. It was not possible from the first investigations, made by either department, to state whether the problem was either purely chemical or biological, or a combination of the two, with the effect of pathogenic soil fungus as a contributory factor. It accordingly appeared desirable to try a series of preliminary soil treatments to see what effect could be produced by remedial measures.

Nematode Treatments on the Mainland and Abroad

A careful survey has been made of the methods of nematode treatment employed with various crops both on the mainland of the United States and in Europe. We shall not attempt to give a detailed resume of all the investigations which have been carried out in this field of endeavor, inasmuch as very few of the methods employed are applicable to cane fields where the land is continuously cropped. We shall, therefore, enumerate briefly the various heads under which such treatments might be grouped.

Soil Sterilization: A partial sterilization of the soil has been used principally with greenhouse soils. Steam has been one of the most effective methods of removing the nematode population, but a wide variety of chemicals have been tried. Among these may be mentioned calcium cyanamid, sodium cyanide used alone and combined with ammonium sulfate, cresol, creosote, crude carbolic acid, ammonium carbonate, copper sulfate, sulfur, and potassium xanthate. Of these chemical reagents, the most favorable reports have appeared regarding the possible field use of calcium cyanamid. Van Zwaluwenburg has reported on the use of several of these materials in Hawaii (7) in connection with his studies of the soil fauna. For the reduction of minute insects similar to *Isotomodes* he found potassium xanthate offered some possibilities. The reduction of soil population, however, was not sufficiently complete to encourage us to believe that nematodes could be controlled in the cane fields by this method.

Catch Crops: The use of catch crops, to which the nematodes are attracted and then killed by pulling up or plowing out the plants, has been tried on both the mainland and abroad. This method is also under trial on pineapple lands in Hawaii. A variation in the method of treatment used by Müller and Molz (4) on sugar beet land, in Germany, is to destroy the catch crop and nematodes by means of a corrosive liquid, such as 30 per cent ferrous sulphate. It is reported that succeeding crops of beets were notably improved by this method of operation. For cane land this procedure has the manifest disadvantage that it involves the loss of a portion of the growing time of one crop, in addition to the expense of the various cultural operations which are involved.

Fallowing: The use of a bore fallow, with a change of the crop grown on the land after such a period, has made a notable reduction in the nematode infestation in a number of mainland experiments. The success of such a method depends on the reported inability of certain species of nematodes to adapt themselves to a

new host plant. This plan has the same disadvantages for sugar lands that have been mentioned in connection with catch crops.

Predatory nematodes: Cobb (1) first proposed that the nematodes might be reduced in a soil by certain predatory nematode species of *Mononchus.* The possibility of cultivating *Mononchus papillatus* and related predators was studied by Steiner and Heinly (5), who concluded that it was possible to grow *Mononchus* in pure cultures. Later, Thorne (6) carried out an intensive investigation of the life history, habits and economic importance of some species of *Mononchus.* He concluded that the *Mononchus* population of a single field was subject to wide fluctuations. Their period of active reproduction was not found to coincide with that of *Heterodera schachtii,* hence the chance of reduction of this harmful species by *Mononchus* was greatly reduced.

Experimental Work

In choosing the materials to be employed in our experiments we were guided largely by the field observations of Muir, in which he had noted the improved root growth that had been found in areas which had received applications of mud press, molasses and organic matter. We, accordingly, chose two soils from widely separated areas of poor cane in central Maui. Sufficient soil was collected from each poor spot to fill fourteen large concrete tubs, 2 feet square and 2 feet deep. Each container held approximately 500 pounds of soil. The following duplicate treatments were installed on each soil: Molasses was applied at the rate of 40 tons per acre; mud press was likewise used at the rate of 40 tons per acre. Lime and phosphate, equivalent to the amounts added in the mud press, were applied at the rate of 1000 pounds per acre of CaO and 1,470 pounds per acre of P_2O_5. Organic matter, derived from composted cane trash, was used at the rate of 70 tons per acre. Sulphur had been employed, previously, in some preliminary field treatments in central Maui, at the rate of 1,000 and 2,000 pounds per acre. No noticeable effect was produced by these amounts. In the meantime, we had seen a statement of Henricksen (3) of Porto Rico that reduction of nematodes was obtained by the above amounts of sulfur. This effect appeared to be ascribed to a change of the soil reaction. In order to obtain a notable change in soil reaction in our experiment, we increased the application to 5 tons of sulfur per acre. We likewise applied "sulphogerm," an inoculated gypsum and sulfur mixture, at the rate of 5 tons per acre.

The above treatments upon the poor soil were contrasted with control tubs of the untreated poor soils and with one tub of poor soil treated with molasses at the rate of 60 tons per acre, and one tub of poor soil subjected to partial sterilization. Duplicate control tubs of soil from adjoining areas of good cane were collected for a further comparison. All the soil treatments were made approximately two and a half months before the tubs were planted. The variety used in both series was H 109. Each tub was planted with two selected top seed pieces, which were thinned to the most uniform plant, soon after germination had taken place.

When the plants had reached a height of approximately one foot, inoculations of cane roots from central Maui, containing *Heterodera* nematodes, were added to all the tubs except those which had received the sulfur treatments. The cane

growth was very backward in the four sulfur tubs and it was decided not to add nematodes. Later observations showed that a sufficient number of nematodes were present in the soil to furnish a heavy inoculation of the roots. All the tubs received a uniform fertilization with mixed fertilizer containing 6 per cent of phosphoric acid, 11 per cent of total nitrogen, and 6 per cent of potash, applied at the rate of 1,000 pounds per acre.

Yields of Cane and Tops at Harvest

The experiment was harvested at the end of five months' growth, as this was approximately the time which we have found it possible to grow cane in tubs of the size employed, and still obtain a normal development of cane and tops. The yield of cane and tops is given in Table I. It will be seen that there was a fairly good agreement between the duplicate tubs. The outstanding result from the harvesting data is the notable increase in cane growth obtained in the tubs which were treated with mud press, molasses and organic matter.

TABLE I

YIELD OF CANE AND TOPS ON TWO SOILS FROM CENTRAL MAUI WITH VARIOUS TREATMENTS FOR NEMATODE CONTROL

Soil from Field 18—Kihei

Tub No.	Character of Soil	Treatment	Yield Grams	Average of Duplicate Treatments
1	Good soil	None	1770	1685
2	" "	"	1601	
3	Poor soil	Molasses—40 tons per acre	3140	3350
4	" "	"	3560	
5	" "	Mud press—40 tons per acre	3797	4223
6	" "	"	4649	
7	" "	Lime and phosphate equal to mud press	2764	2708
8	" "	"	2652	
9	" "	Organic matter—70 tons per acre	3890	4553
10	" "	"	5216	
11	" "	Sulphogerm—5 tons per acre	2440	2605
12	" "	"	2770	
13	" "	Sulphur—5 tons per acre	Dead	
14	" "	"	Dead	
15	" "	Partial sterilization	4009	
16	" "	None	1319	
		Soil from Field 2		
17	Good soil	None	3642	3822
18	" "	"	4002	
19	Poor Soil	Molasses—40 tons per acre	4040	4488
20	" "	"	4936	
21	" "	Mud press—40 tons per acre	4932	4965
22	" "	"	4998	
23	" "	Organic matter—70 tons per acre	5475	6876
24	" "	"	8278	
25	" "	Lime and phosphate equal to mud press	3150	3615
26	" "	"	4080	
27	" "	Sulphogerm—5 tons per acre	3272	3197
28	" "	"	3122	
29	" "	Sulphur—5 tons per acre	2142	1707
30	" "	"	1272	
31	" "	Molasses—60 tons per acre	4432	
32	" "	None	2260	

Examination of Cane Roots

The roots of the stools of harvested cane were examined for nematodes by Cassidy and Van Zwaluwenburg. The detailed results of these examinations are given in Table II.

TABLE II

EXAMINATION OF H 109 CANE ROOTS FOR NEMATODES

Tub No.	Soil	Treatment	Nematodes Found in the Soil, Degree of Infestation: Tylenchus Similis	Heterodera Schachtii	Heterodera Radicicola	Original Root Growth	Condition of Roots at Harvest as Regards Decay
1	Good soil, Fld. 18, Kihei	None	.....	Heavy	....	Good	Fair
2	"	None	.....	Heavy	....	Excellent	Fairly good
3	Poor soil, Fld. 18, Kihei	Molasses—40 tons per acre	.....	Light	....	Very good	Excellent
4	"	"	Light	....	Light	Excellent	Good
5	"	Mud press—40 tons per acre	.....	Very light	....	Very good	Good
6	"	"	Light	Light	Light	Excellent	Fairly good
7	"	Lime and phosphate equal to mud press	Heavy	Heavy	....	Excellent	Poor
8	"	"	Heavy	Heavy	Heavy	Very good	Good
9	"	Organic matter—70 tons per acre	.....	Very light	....	Very good	Excellent
10	"	"	Light	Light	Light	Excellent	Good
11	"	Sulphogerm—5 tons per acre	Heavy	Heavy	....	Very good	Very poor
12	"	"	.....	Heavy	Heavy	Very good	Fair
13	"	Sulphur—5 tons per acre				Dead	
14	"	"				Dead	
15	"	Partial sterilization	.....	Moderate	....	Excellent	Good
16	"	None	Heavy	Heavy	Heavy	Poor	Poor
17	Good soil, Fld. 2	None	Heavy	Heavy	....	Good	Poor
18	"	None	Heavy	Heavy	Heavy	Excellent	Fair
19	Poor soil, Fld. 2	Molasses—40 tons per acre	.....	Moderate*	....	Very good	Good
20	"	"	.....	Very heavy	Very heavy	Excellent	Good
21	"	Mud press—40 tons per acre	.....	Very light	....	Excellent	Excellent
22	"	"	.....	Moderate	....	Very good	Good
23	"	Organic matter—70 tons per acre	.....	Heavy	....	Excellent	Very good
24	"	"	Very few	....	Light	Excellent	Excellent
25	"	Lime and phosphate equal to mud press	.....	Heavy	....	Good	Poor

* Culture 19 roots were likewise found to contain *Mononchus* and *Tylencholaimellus* in moderate numbers.

26	Poor soil, Fld. 2	Lime and phosphate equal to mud press	.....	....	Moderate	Very good	Good
27	"	Sulphogerm—5 tons per acre	.....	Heavy	....	Excellent	Fair
28	"	"	.....	....	Moderate	Fair	Good
29	"	Sulphur—5 tons per acre	.....	One specimen	....	Fair	Excellent
30	"	"	.....	....	....	Poor	Good
31	"	Molasses—60 tons per acre	.....	Moderate	....	Very good	Good
32	"	None	.....	....	Moderate	Fairly good	Fair

The above data may be summarized as follows:

Molasses added to poor soils produced excellent growth, with an absence of decay and a moderate infestation of nematodes, compared with untreated soil.

Mudpress produced roots similar to the molasses treatment on both poor soils. There were a notably smaller number of nematodes present than in the untreated poor soil.

Organic matter produced excellent roots when added to the poor soils. There was only a light infestation of nematodes.

Lime and phosphates: The original root growth was good, but breakdown and decay of the roots occurred later.

Sulphur not inoculated: In one soil the sulphur treatment produced an entire failure of growth; in the other there was a poor development of roots. Nematodes were present, though no inoculation was made with infested roots.

Sulphogerm: The average root growth was good, but the nematode infestation was heavy. These nematodes were brought in the soil, none were added.

Partial sterilization of poor soil: The root growth was better than in the untreated soil.

The general conclusion to be drawn from these observations upon the different treatments is that the best root development corresponded with the improved top growth occurring in part of the cultures. This improvement of root and top growth showed the value of the treatments with molasses, mud press and organic matter.

Examinations of the Soils for Nematodes

Uniform samples of soil from each tub were examined by K. J. Pratt, under the direction of Van Zwaluwenburg. These examinations revealed the entire numbers of nematodes living in the soil outside the cane roots. This would include nematode species which are not harmful to cane plants, as well as those which attack the roots.

TABLE III

EXAMINATION OF SOIL SURROUNDING CANE STOOLS FOR NEMATODES

Tub No.	Soil	Treatment	Nematodes Found in the Soil, Degree of Infestation: Tylencholaimellus	Prismatolaimus	Hoplolaimus	Dorylaimus	Mononchus
1	Good soil, Fld. 18, Kihei	None	....	....	....	Heavy	....
2	"	None	Very light	....	....	Heavy	....
3	Poor soil, Fld. 18, Kihei	Molasses—40 tons per acre	....	....	....	Moderate	....
4	"	"	....	....	....	Light	....
5	"	Mud Press—40 tons per acre	....	....	....	Light	....
6	"	"	....	....	....	Light	....
7	"	Lime and Phosphate equal to Mud Press	....	....	Heavy	Light	....
8	"	"	....	....	Heavy	Light	....
9	"	Organic Matter—70 tons per acre	....	....	Heavy	....	....
10	"	"	....	....	Heavy	Light	....
11	"	Sulphogerm—5 tons per acre	....	....	Light	Light	....
12	"	"	....	....	Light	Light	....
13	"	Sulphur—5 tons per acre	....	....	....	....	....
14	"	"	....	....	....	Very light	....
15	"	Partial Sterilization	....	....	....	Moderate	....
16	"	None	....	....	Light	Moderate	Very light
17	Good soil, Fld. 2	None	....	....	....	Fairly heavy	....
18	"	None	....	....	....	Heavy	....
19	Poor soil, Fld. 2	Molasses—40 tons per acre	Very light	Very light	....	Moderate	Heavy
20	"	"	....	....	....	Light	Very light
21	"	Mud Press—40 tons per acre	....	....	Light	Moderate	....
22	"	"	....	....	....	Very light	....
23	"	Organic Matter—70 tons per acre	....	....	Moderate	Light	Very light
24	"	"	....	....	Light	Moderate	....
25	"	Lime and Phosphate equal to Mud Press	....	....	Moderate	Moderate	Very light
26	"	"	....	....	Light	Moderate	One specimen
27	"	Sulphogerm—5 tons per acre	....	....	....	Light	....
28	"	"	....	....	....	Very Moderate	....
29	"	Sulphur—5 tons per acre	....	....	....	Light	....
30	"	"	....	....	....	Light	....
31	"	Molasses—60 tons per acre	....	....	....	Light	Heavy
32	"	Untreated	....	....	....	Moderate	Very light

The detailed results are given in Table III, but the most important conclusions may be summarized by the following observations: The tubs of untreated good soil were found to contain a greater number of nematodes than any of the other soils. The partial sterilization of the poor soil caused a notable reduction in nematode numbers. The heavy applications of sulphur and of "sulphogerm" both caused a definite reduction in the nematode population. *Dorylaimus,* a genus containing several species which attack cane, was the most common nematode found in all the tubs of the series. This variety was reduced in numbers in the sulphur-treated soils.

The slightly more colloidal soil from Field 18, Kihei, when treated with organic matter, or with lime and phosphoric acid, contained large numbers of *Hoplolaimus.* This spear-bearing nematode is often found in enormous numbers in cane soils, but is not known to attack sugar cane root.

The molasses treatments, in the more open, permeable soil from Field 2, appeared to favor the increase of the predatory nematode, *Mononchus.* This suggests an added point in favor of molasses treatments for nematode-infested soils.

Examination of Soil Fauna Other Than Nematodes

Representative portions of soil were collected about three inches below the surface among the roots of the cane at the time of harvest. These samples were examined by Van Zwaluwenburg for soil inhabitants other than nematodes. The most numerous of the minute insects present in the soil were the *Isotomodes.* A few representatives of Pauropoda, Entomobryids, Sminthurids and mites were found in various tubs. The latter organisms were present in such scattering numbers that no consistent conclusion could be drawn as to their presence or absence. It was, however, noted that the sulfur treatments reduced the number of incidental organisms and also the *Isotomodes* present in these tubs. Partial sterilization removed the small insect soil inhabitants and none had found their way into the soil during the growth of the plants. Organic matter caused an appreciable increase of the soil fauna, but in the presence of this adequate food supply, very few cane roots were attacked.

Chemical Changes Produced by Soil Treatments

The chemical changes in the soils produced as a result of the various treatments were studied by Stewart and Hansson. The analyses made upon the soils included the determination of the soil reaction and the composition of the displaced soil solutions. These results are given in Table IV. Determinations were made also of the replaceable bases in the principal treatments.

The first comparison to be made is the difference between the displaced soil solution of the two good and two poor soils. In the case of the soils from Field 18, the poor soil was slightly more alkaline than the soil from the adjoining good portion of the field, but there was no great difference in the content of the principal constituents present in the soil solution of either portion of the field. In the case of the soils from Field 2, the content of most of the major constituents in the two

TABLE IV. ANALYSIS OF DISPLACED SOIL SOLUTIONS OF GOOD AND POOR SOILS FROM CENTRAL MAUI

Results expressed as parts per million in the soil solution.

Tub. No.	Treatment	P. P. M. Total Solids	P. P. M. Organic Matter Etc.	P. P. M. Non-Volatile Residue	P. P. M. Carbonates CO_3	P. P. M. Bi-Carbonates HCO_3	P. P. M. Chlorides Cl	P. P. M. Nitrate Nitrogen N	P. P. M. Sulphates SO_4	P. P. M. Phosphates P_2O_5	P. P. M. Calcium Ca	P. P. M. Magnesium Mg	P. P. M. Sodium Na	P. P. M. Potassium K	P. P. M. Iron Fe_2O_3	P. P. M. Alumina Al_2O_3	P. P. M. Silica SiO_2	Soil Reaction pH
Tubs 1 and 2	Good soil, Fld. 18, Kihei	946.0	78.0	868.0	None	36.6	329.8	15.0	236.0	0.2	19.9	51.4	257.2	23.0	2.4	0.2	8.0	7.34
Tubs 3 and 4	40 tons Molasses	1406.0	312.0	1094.0	12.0	198.2	336.9	22.8	165.1	0.2	74.0	57.2	178.6	148.8	2.4	0.6	9.2	7.93
Tubs 5 and 6	40 tons Mud Press	1192.0	224.0	968.0	None	204.4	347.5	10.4	152.9	0.7	84.0	54.5	212.8	19.5	1.6	0.4	16.8	8.27
Tubs 7 and 8	Lime and P_2O_5, Equiv. to Mud Press	2704.0	308.0	2396.0	None	106.7	340.4	9.6	1256.9	0.3	283.3	132.4	276.1	57.1	1.4	0.4	20.6	7.93
Tubs 9 and 10	70 tons Decomposed Trash	1360.0	334.0	1026.0	6.0	152.5	230.5	36.5	189.9	Trace	77.6	54.5	210.0	31.9	2.6	1.4	28.0	7.93
Tubs 11 and 12	5 tons Sulphogerm	3958.0	454.0	3504.0	None	33.5	347.5	12.0	2064.1	0.5	292.4	284.7	353.5	46.0	1.2	0.8	20.4	7.25
Tubs 13 and 14	5 tons Sulphur	58066.0	14116.0	43950.0	None	None	570.9	6.6	16536.9	12.8	562.8	871.0	907.7	222.7	42.5	8675.9	306.8	3.28
Tub 16	Untreated Poor Soil, Fld. 18	1560.0	170.0	1390.0	None	79.3	301.4	34.5	390.4	0.2	77.4	57.9	287.3	30.4	4.4	0.6	15.6	8.18
Tubs 17 and 18	Good Soil, Fld. 2	988.0	148.0	840.0	None	195.2	191.5	9.0	172.0	0.2	25.6	17.8	242.0	29.7	5.0	1.0	30.4	8.01
Tubs 19 and 20	40 tons Molasses	1058.0	290.0	768.0	15.0	189.1	170.2	22.8	125.9	0.9	62.8	38.1	119.7	104.4	2.6	0.4	32.6	7.76
Tubs 21 and 22	40 tons Mud Press	916.0	222.0	694.0	33.0	301.9	191.5	0.6	88.2	3.8	70.4	42.4	141.4	18.0	1.6	0.2	34.6	8.01
Tubs 23 and 24	70 tons Decomposed Trash	1084.0	292.0	792.0	15.0	323.3	195.0	3.6	94.6	0.9	71.8	46.1	182.4	25.6	2.6	2.0	39.6	7.68
Tubs 25 and 26	Lime and P_5O_2, Equiv. to Mud Press	2128.0	344.0	1784.0	None	244.0	195.0	0.3	948.6	2.0	319.4	92.4	164.2	32.5	1.2	0.4	26.4	7.68
Tubs 27 and 28	5 tons Sulphogerm	1250.0	246.0	1004.0	None	36.6	187.9	26.0	359.1	0.9	108.0	43.9	154.1	25.8	2.0	0.4	42.4	7.08
Tubs 29 and 30	5 tons Sulphur	4132.0	508.0	3624.0	None	None	113.5	2.3	1784.0	0.2	57.4	142.5	165.5	55.6	4.2	125.6	151.6	4.21
Tub 32	Untreated Poor Soil	880.0	198.0	682.0	None	42.7	166.6	30.0	136.1	0.5	37.8	24.6	170.3	19.1	2.0	0.2	23.8	7.76

soils was very similar. There was a slightly higher content of potassium in the soil solution from the good portion of the field, but there were few other consistent differences between the two soils. It should be noted that the good and poor soils in each case were selected only on the basis of the growth of the cane in both areas at the time of the collection of our large samples. It was known that poor places had been present in the same general locations in these fields during previous crops. The exact boundaries of the poor areas could not, however, be definitely established. In other words, it is not absolutely certain that the good portions of the field in the vicinity of the poor areas were certain to produce good cane at all times.

The general similarity of the soils collected as good and poor is shown by the determinations of replaceable bases given in Table V.

The figures for the per cent of replaced bases in both good and poor soils show that both groups of soils contain larger percentages of replaceable sodium and magnesium, in relation to the percentage of replaceable calcium, than is desirable for the best plant growth.

The effect of the various treatments upon the soil reaction and the constituents present in the soil solution was not the same for the two poor soils. This is clearly shown by the changes in the soil reaction which were caused by the addition of sulfur to each soil. The 5-ton per acre application of sulfur caused a toxic acidity of 3.28 pH, and a dangerous concentration of soluble iron and aluminum in the soil from Field 18. The soil from Field 2 was less acid in its original reaction, but there was evidently a larger alkaline reserve in the soil. The reaction developed by the sulfur in this case was pH 4.2, and the amounts of iron and aluminum brought into solution were notably smaller. For the sake of simplicity, we shall summarize the more striking effects of the various treatments upon the two soils.

Molasses: The molasses treatment upon one soil caused a slight decrease in soil alkalinity; with the other soil, there was no change in reaction. The molasses caused a definite increase in soluble organic matter in both soils, an increase in the potash present in the soil solution, and a large increase in the replaceable potash.

Mud press: The mud press treatments caused a smaller increase in soluble organic matter than occurred with molasses. The mud press caused a definite increase in the phosphate content of the soil solution of both soils. The calcium content was slightly changed with one soil and doubled with the other. The magnesium present in the soil solution was increased in one soil but was unchanged in the other. In one soil the potassium content of the soil solution was reduced, as was also the replaceable potassium held in the soil. There was a slight increase in the alkalinity of the soil reaction.

Lime and phosphate: The application of these materials in amounts equal to that supplied by the mud press caused a larger liberation of soluble organic matter than occurred with mud press. There was, however, a smaller increase of phosphates in the soil solution than was caused by mud press. The lime and phosphate gave a greater liberation of soluble calcium and freed more soluble magnesium. There was also an increase of soluble potassium in the soil solution and a corresponding decrease in the replaceable potassium held in the soil. There was no appreciable change in soil reaction.

TABLE V. REPLACEABLE BASES AND SOIL REACTION IN TUBS OF GOOD AND POOR SOIL FROM CENTRAL MAUI

Calculated to Water Free Soil.

		Per Cent of Bases Replaced in the Soil, Together with the Change in Silica, Iron and Alumina, and Sulphates Found in the Replacing Solutions								Per Cent of Total Replaced Bases				Soil Reaction
		% Silica	% Iron and Alumina		% Sulphate	% Calcium	% Magnesium	% Sodium	% Potassium	% Calcium	% Magnesium	% Sodium	% Potassium	
Tub Nos.	Treatment	SiO_2	Fe_2O_3	Al_2O_3	SO_4	Ca	Mg	Na	K	Ca	Mg	Na	K	pH
Tubs 1 and 2	Good Soil, Fld. 18, Kihei	.0038		.0161	.0307	.1190	.0760	.0996	.0581	33.74	21.55	28.24	16.47	7.34
Tubs 3 and 4	40 tons Molasses	.0220		.0110	.0275	.2520	.0994	.0825	.1430	43.69	17.23	14.30	24.78	7.93
Tubs 5 and 6	40 tons Mud Press	.0059		.0034	.0207	.2870	.0990	.0611	.0256	60.72	20.94	12.93	5.41	8.27
Tubs 7 and 8	Lime and P_2O_5, Equiv. to Mud Press	.0123		.0110	.0974	.3630	.0796	.0700	.0374	66.00	14.47	12.73	6.80	7.93
Tubs 9 and 10	70 tons Decomposed Trash	.0064		.0042	.0273	.3020	.1080	.0732	.0467	57.00	20.38	13.81	8.81	7.93
Tubs 11 and 12	5 tons Sulphogerm	.0106		.0025	.1510	.2360	.0754	.0733	.0399	55.58	17.76	17.26	9.40	7.25
Tubs 13 and 14	5 tons Sulphur	.0137		.4633	1.8660	.2212	.0652	.0695	.0331	56.87	16.76	17.87	8.50	3.28
Tub 16	Untreated Poor Soil	Nil		.0051	.0380	.2661	.0965	.0965	.0541	51.86	18.80	18.80	10.54	8.18
Tubs 17 and 18	Good Soil, Fld. 2, Co. 3	Nil		.0083	.0317	.3112	.1087	.1328	.1188	46.35	16.19	19.78	17.68	8.01
Tubs 19 and 20	40 tons Molasses	Nil		.0050	.0221	.2465	.0750	.0707	.1520	45.30	13.78	12.98	27.94	7.76
Tubs 21 and 22	40 tons Mud Press	.0033		.0066	.0219	.3080	.0929	.0659	.0606	58.40	17.61	12.50	11.49	8.01
Tubs 23 and 24	70 tons Decomposed Trash	.0037		.0058	.0144	.3135	.0946	.1048	.0715	53.64	16.19	17.93	12.24	7.68
Tubs 25 and 26	Lime and P_2O_5, Equiv. to Mud Press	.0012		.0045	.0437	.3134	.0584	.0628	.0582	63.60	11.85	12.74	11.81	7.68
Tubs 27 and 28	5 tons Sulphogerm	.0051		.0051	.0288	.2478	.0553	.0692	.0556	57.92	12.92	16.17	12.99	7.08
Tubs 29 and 30	5 tons Sulphur	.0174		.1264	.6580	.2524	.0107	.0341	.0239	78.61	3.33	10.62	7.44	4.21
Tub 32	Untreated Poor Soil	.0008		.0033	.0192	.1971	.0595	.0748	.0555	50.95	15.38	19.33	14.34	7.76

Organic matter: The heavy application of decomposed organic matter, derived from cane trash, caused a material increase in soluble organic matter. There was an appreciable increase in the bicarbonates present in the soil solution but no material change in any of the major constituents.

"Sulphogerm": The application of this gypsum and sulfur material caused an increase of soluble organic matter. There was likewise a notable increase in the content of soluble calcium, sulphates and magnesium. This material caused a slight increase in the content of soluble potassium in the soil solution and a corresponding decrease in replaceable potash.

Sulphur: The sulphur applications were excessive for plant growth, as we had wished to determine the maximum effect on the soil fauna, including nematodes. We have previously noted the material increase in soil acidity. This acidity acted on all the soil minerals to free material quantities of the major constituents of the soil solution, including a high content of iron and aluminum in one soil and a material increase of these materials in the other.

Conclusions: The foregoing observations upon cane growth, root development, soil inhabitants and chemical changes in the soil as the result of our various treatments can only be regarded as furnishing evidence of a preliminary nature. The indications are, from our chemical examination of the soils, that both the soils classed as being definitely poor and the so-called good soils verge over to the border line of an unfavorable chemical environment, owing to the ratio of replaceable calcium to replaceable magnesium and sodium. Definite improvement in root growth and cane development was caused by applications of mud press, molasses, and decomposed cane trash. A much smaller increase was caused by lime and phosphates equal to the amounts added in the mud press than was given by the mud press itself. This points to the probable influence of the organic content of the mud press as a great factor in its beneficial effect.

Chemical studies of the displaced soil solutions of the treated and untreated soils, as well as the determination of the soil reaction and content of replaceable bases, indicated that an increase in the content of soluble organic matter was the one factor which was common to all three types of treatment which gave the most favorable results. It therefore appears probable that the favorable influence exerted by the mud press, organic matter and molasses, is more largely a biological effect than a chemical one. We are replanting the tubs to determine whether the residual effect of the favorable treatments continues to a second cane crop.

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A Study of the Effect of Nematodes Upon Cane Roots in Sterilized Soils

By Guy R. Stewart and Fred Hansson

In the October *Record* for 1925 (2), a preliminary report was given upon the relative effects of various types of root-attacking organisms upon cane roots. In this first experiment, which was carried out as a joint endeavor by the departments of chemistry and entomology, the root growth of Lahaina cane was compared in the presence and absence of nematodes, small centipedes, and minute snails. One of the soils used was from highly acid land on which Lahaina cane had failed in the early days. The other soil employed was from good land upon which Lahaina cane was growing well. A portion of the tubs of acid soil were treated with lime and phosphates to neutralize the acidity, and a toxic concentration of salts was added to half of the tubs of good soil. It was, therefore, possible to study the effect of the root-attacking organisms upon the plant under conditions which were both favorable and unfavorable for cane growth.

The soils were all subjected to partial sterilization to kill insect and animal life, but still contained the usual flora of fungi and bacteria. The general conclusions drawn from this experiment were that small centipedes and snails did not survive in sufficiently large numbers in our tubs to exercise any great influence upon root development. In partially sterilized soil, toxic acidity and a high concentration of salts were less harmful than is ordinarily the case in the field. Notable root destruction and a stunted top growth were found in all the tubs where free living nematodes, largely *Tylenchus similis,* were added to the soil.

Since the time of this preliminary experiment, our knowledge of the effect of root-attacking organisms has been greatly extended by the work of Muir, Van Zwaluwenburg and Dr. Gertrude Cassidy. Van Zwaluwenburg's reports to the Association of Hawaiian Sugar Technologists in 1926 (3), and 1927 (4) clearly show that the minute spring-tailed insect, *Isotomodes,* is usually the principal factor in causing the small pits which have been commonly noted in cane roots. Under the ordinary conditions of cane culture, where there is an appreciable amount of organic matter in the soil as the result of the partial decomposition of cane trash and cane roots, it was found that the cane plant suffered little apparent damage from the attacks of the *Isotomodes.* Where organic matter was almost entirely

lacking, Van Zwaluwenburg found that the *Isotomodes* might turn upon the cane roots as a principal source of nourishment.

Barnum and Van Zwaluwenburg (1) have carried out a valuable experiment in which they have studied the root destruction of Lahaina cane in the presence of *Isotomodes* and *Pythium* fungus. This work was carried out in sterile soil from the Makiki plots. "The combined attacks of *Pythium* and *Isotomodes* produced more serious effects on Lahaina cane than did either organism separately." The results of such studies point to the necessity of further work in which the definite effect of various root-inhibiting factors is determined, both separately and in combination.

The plantation surveys of nematode conditions in the cane fields which have been carried out by Van Zwaluwenburg and Dr. Cassidy have proven of great value in developing our knowledge of the extent to which these organisms are normally present in cane roots. In general, it may be stated that nematodes do not appear to be, ordinarily, a large factor in the destruction of cane roots over extensive areas of cane land. Under unusual conditions they have increased, temporarily, to a point where their presence may be a menace to the development of a succssful crop. Such is the case in various poor spots of the cane fields of central Maui. A study of the relationship of the various soil conditions to the development of nematodes in the soils of such poor spots appears as a companion article in this issue of the *Record*.

In considering the relationship between soil environment and nematode development it became evident that we possessed practically no information as to the effect which nematodes would have were they present in cane roots, without large numbers of fungi and bacteria present in the soil. In other words, did the cane roots break down as a result of the attacks of the nematodes alone, or was the root destruction the result of the entrance of the fungi and bacteria which accompanied the nematodes?

A cooperative experiment was therefore planned between the departments of chemistry and entomology in which sterilized cane cuttings were to be grown in completely sterile soil. Pure cultures of nematodes were to be added to a portion of the cane plants and the effect upon root development and root destruction would be carefully studied. It should be pointed out that, although the nematodes which were added to the cultures were washed with several treatments of sterile water, they were still contaminated by the presence of some bacteria. The reduction in the numbers of fungi and bacteria present in the soil, though quite large, was not complete, owing to the subsequent contamination from the nematode cultures.

Experimental Work

Two notably different types of soil were chosen for use in our pot cultures. One soil was a heavy, black, clay adobe, from the lower fields of Waimanalo Sugar Company. The other soil was a highly acid red clay loam from the Kaneohe district, upon which Lahaina cane had failed in the early days.

A series of thirty-two pots were filled with each soil. Those containing the Waimanalo soil held 30 pounds of soil and the pots of Kaneohe soil each held 35

pounds of soil. Before sterilization, half the pots of Waimanalo soil were treated with a mixture of salts similar to the residue left by a saline irrigation water in sufficient quantity to cause a concentration of 15,000 parts per million of soluble salts. Half of the pots of Kaneohe soil were treated, at the same time, with sufficient lime and superphosphate to neutralize the unfavorable acidity. In order to avoid contamination, all the treatments were added to the individual pots and the soil was sterilized without further handling. The top of each pot was covered with heavy paper and sets of pots were then subjected to steam sterilization for three hours at 15 pounds pressure upon three successive days. Upon completing the sterilization, a soil suspension was made up in sterile water from portions of each soil drawn from the center of extra jars of soil. Upon plating out these soil suspensions, the sterilized soils are found to be absolutely free from fungi and bacteria. It will be seen that the above treatments left half the pots of each soil with a favorable chemical environment for cane growth, and the other half with a distinctly unfavorable chemical condition. The scheme is summarized in Table I.

TABLE I. TREATMENT OF STERILIZED SOILS

Soil Used	Treatment of Soil	Planted to Lahaina Cane	Planted to H 109 Cane
Kaneohe	None	8 pots	8 pots
Kaneohe	Superphosphate and Lime	8 "	8 "
Waimanalo	None	8 "	8 "
Waimanalo	Salts added	8 "	8 "

Half the pots filled with each soil were planted to Lahaina cane and the other half to H 109. The seed pieces used were one-eye cuttings which were covered at each end with hot sealing wax. In order to reduce contamination to the minimum the cuttings were immersed in a 4 per cent formaldehyde solution for a period of three minutes, then washed in sterile water and planted.

The germination of the seed pieces, under these conditions was very slow, and several replantings were necessary before we obtained growth in all the pots. The later development of the plants was rather deliberate, even though all the cultures were fertilized with sterilized mixed fertilizer applied at the rate of 1000 pounds per acre foot of soil. The mixed fertilizer had the following formula: total nitrogen 12 per cent, phosphoric acid 5 per cent, and potash 10 per cent.

After the plants had reached a height of six inches, a portion of the pots of each of the eight sets were inoculated with pure cultures of three species of root-attacking nematodes. The cultures were isolated and furnished us by F. Muir and Dr. Cassidy, of the entomology department. The three species of nematodes used were *Tylenchus similis, Heterodera schachtii* and *Dorylaimus.*

The plants were grown for a period of approximately six months after the addition of the nematodes. The development of leaf and stalk was very deliberate. The final growth of the plants was comparatively small. There was no essential difference between the size of the plants grown in either the favorable or unfavorable chemical state of each soil. This is shown clearly in the accompanying photograph, which shows the development of four typical pots of Lahaina cane.

Uniform growth of cultures in the presence and absence of nematodes.

The treatments illustrated are as follows:

Pot No. 1, Kaneohe soil, no treatment except sterilization, no nematodes.
Pot No. 2, Kaneohe soil, no treatment except sterilization, nematodes added.
Pot No. 3, Kaneohe soil, sterilized, lime and superphosphates added, no nematodes added.
Pot No. 4, Kaneohe soil, sterilized, lime and superphosphates added, nematodes added.

The growth of the plants in the Waimanalo soil was similar to that of the Kaneohe cultures. No appreciable effect upon the top growth of the plants was noted after the nematodes had been added to the various groups of cultures included in the experiment.

After the period of growth at which the photograph in the illustration was taken, all the pots treated with nematodes were examined by Dr. Cassidy and Mr. Van Zwaluwenburg, and the types of nematodes present in them were tabulated. Comparison plots to which no nematodes had been added were likewise examined. The results of these examinations are given in Table II.

TABLE II

RESULTS OF EXAMINATION BY ENTOMOLOGISTS OF NEMATODE EXPERIMENT WITH STERILE SOIL

Soil	Treatment	Cane Variety	Nematodes Added	Nematodes Found	Root Condition
Waimanalo	Sterilized No Salts	H 109	None	None	Root growth fair.
Waimanalo	Sterilized No Salts	H 109	Tylenchus	Tylenchus	Root growth poor. Typical Tylenchus lesions, little deterioration.
Waimanalo	Sterilized No Salts	H 109	Tylenchus	Tylenchus	Root growth poor. No Tylenchus lesions noted. Roots in fair condition.
Waimanalo	Sterilized No Salts	Lahaina	Heterodera	None	Root growth very poor. No deterioration. No galls.
Waimanalo	Sterilized No Salts	Lahaina	Tylenchus	Tylenchus	Root growth very poor. No deterioration.
Waimanalo	Sterilized Salts added.	H 109	Heterodera	None	Root growth fairly good. No deterioration. A few apical galls.
Waimanalo	Sterilized Salts added.	H 109	Tylenchus	None	Root growth poor. No deterioration.
Kaneohe	Sterilized	H 109	None	None	Root growth fair.
Kaneohe	Sterilized	H 109	Heterodera	None	Root growth fair. No deterioration. No galls.
Kaneohe	Sterilized	H 109	Tylenchus	Tylenchus	Root growth poor. No deterioration.
Kaneohe	Sterilized	H 109	Dorylaimus	None	Root growth poor. No deterioration.
Kaneohe	Sterilized	Lahaina	Heterodera	None	Root growth good. No deterioration. No galls.
Kaneohe	Sterilized	Lahaina	Heterodera	None	Root growth good. A few older roots rotted. No galls.
Kaneohe	Sterilized	Lahaina	Tylenchus	None	Root growth poor. No deterioration. One typical Heterodera gall.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Heterodera	None	Root growth fair. No deterioration. No galls.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Tylenchus	Tylenchus	Root growth fair. No deterioration. No galls or red lesions.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Tylenchus	None	Root growth very poor. No deterioration.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Dorylaimus	None	Root growth poor. No deterioration.
Kaneohe	Sterilized Lime and Superphosphate added.	Lahaina	Tylenchus	Tylenchus	Root growth good. No deterioration.
Kaneohe	Sterilized Lime and Superphosphate added.	Lahaina	Tylenchus	Tylenchus	Root growth good. No deterioration.

Several deductions may be drawn from the results given in Table II. It will be seen that in many of the cultures the nematodes had disappeared. This was true of a few of the cultures of *Tylenchus,* but all the cultures in which *Heterodera* and *Dorylaimus* had been added were free from nematodes. None of these two species of nematodes had survived in our pots.

It is undoubtedly true that the conditions of our experiment, in which complete sterility of the soil was achieved at the start, were not the most favorable for plant or animal development. Our plants were grown in closely covered cheesecloth cages to avoid contamination from dust. The only water supplied was sterile water. A small amount of contamination was found to have taken place from a limited number of common molds and bacteria, but this flora was comparatively negligible when contrasted to that originally present in the soil.

A series of ammonification and nitrification tests were carried out on the soils of all the typical cultures, including those with and without nematodes. We found that a few of the soils to which nematodes had been added had been contaminated with nitrifying bacteria. No ammonifying organisms were found in any of the groups of cultures.

It is planned to extend the scope of this experiment at a later date, by the use of additional soils which are more favorable to nematode development. We also hope to obtain the cooperation of the pathologists so that cultures of pathogenic fungi and *Isotomodes,* root-puncturing animals, may be present in part of the pots.

The difficulties of working with these various organisms and maintaining the soils used in anything approaching a sterile condition are very great. In the present experiment a small amount of contamination unquestionably took place, but even so, we feel justified in drawing certain general conclusions from the experiment.

Summary

(1) First and foremost among these conclusions should be placed the fact that none of the three varieties of nematodes multiplied to an appreciable extent when they were placed in contact with cane plants in a practically sterile soil. Under these conditions, only *Tylenchus similis* survived, while *Heterodera* and *Dorylaimus* disappeared. This fact points to the greater vitality and vigor of *Tylenchus similis.*

(2) The root destruction which occurred where nematodes were present in sterile soil was comparatively small. This applied to the cultures in which *Tylenchus* survived as well as to those where *Heterodera* and *Dorylaimus* had been added and probably lived for a time.

(3) The cane growth obtained in the sterile control cultures was smaller than in normal soils, but this moderate growth in the sterile soil was not appreciably reduced by unfavorable chemical conditions of the soil.

(4) Determinations of the sterility of the soil cultures were made at the close of the experiment. It was found that a small contamination with common molds and a few groups of bacteria had occurred. The total numbers present were relatively small.

(5) Further work is required to establish the relationship between root destruction and the presence of nematodes, pathogenic fungi and root-puncturing organisms such as *Isotomodes*.

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The Quinhydrone Electrode for Measuring the Reaction of Hawaiian Soils

By W. T. McGeorge

The development of accurate methods for estimating small variations in hydrogen and hydroxyl ion concentration of aqueous solutions and their application to soil analysis has been of great value in the study of soil properties. The so-called pH has become a byword in soil chemistry.

Colorometric and electrometric methods have both found wide application, more so the latter, because of the difficulty often encountered in obtaining a water extract of the soil sufficiently clear for colorometric comparisons. The electrometric method involving the use of the hydrogen electrode also has its limitations. Reducible substances affect its accuracy. The electrode, which must be coated with a film of platinum black, is subject to "poisoning" and its activity and accuracy is affected thereby. In soils of pH 6.0 to 7.5 the effect of the stream of hydrogen upon the CO_2 in the soil suspension will also often introduce an error. Considerable interest has therefore been aroused in the quinhydrone electrode advocated by Biilman in 1920. This method is somewhat of a departure from the hydrogen electrode method, and is unique in its simplicity. By means of the organic compound quinhydrone it is possible to form an electrode which acts similarly to the hydrogen electrode. Quinhydrone is a combination of one molecule quinone, $C_6H_4O_2$, with one molecule hydroquinone $C_6H_4O_2H_2$ and in aqueous solution is highly associated into these two components. An equilibrium is developed such as illustrated in the following equation:

$$C_6H_4O_2H_2 \rightleftharpoons C_6H_4O_2 + H_2$$

The hydroquinone, in other words, acts as a source of hydrogen. The hydrogen gas stream necessary in using the hydrogen electrode is eliminated. Only clean

platinum electrodes are employed. The poisoning so common where the platinum must be coated with a film of platinum black is thus also eliminated. The preparation of the quinhydrone electrode, as Biilman has stated, is extremely simple and quick and is therefore rapidly coming into general use.

A detailed description of the theory, apparatus and method is not necessary, as a number are available in recent literature. Only a few of the salient points will therefore be mentioned.

A special KC1-HC1 half cell—.01 N/HC1: .09 N/KC1—to which a trace of quinhydrone is added (calomel half cell may also be used), is connected by capillarity with a saturated KC1 solution, and this in turn by a saturated KC1-agar bridge with the soil water suspension (or other unknown) to which approximately .05 gram of quinhydrone per 25 ccs. has been added and into which the second platinum electrode is dipped, completing the chain. From the difference in potential the pH of the unknown may be calculated—correcting for temperature. The chain has been illustrated diagramatically as follows:

Platinum	HC1 .01N	Kcl	Soil	
	KC1 .09N	Saturated	Water	Platinum
	Quinhydrone		Quinhydrone	
	(pH 2.06)			

$$pH = 2.06 + \frac{E.\,M.\,F.}{.0001984\ T}$$

The difference in potential as measured by the potentiometer (E. M. F.) is substituted in the preceding equation for calculating the pH.

During the course of some investigations in soil reaction being conducted by the writer, a knowledge of the application of the quinhydrone electrode to Hawaiian soil types was sought. The titration of soil extracts and colloids are, for example, much simpler and more rapid by this method than by the hydrogen electrode. However, on attempting to apply it to Hawaiian soils some difficulties were met which are of interest.

The problems related to the determination of soil pH are still more or less unstandardized. Reference is made primarily to the variation in ratio of soil to water used in preparing the soil for the determination. In many soils there is no variation in pH with the variation in soil water ratio, but in some notably highly alkaline types, soils high in soluble acidity, and the highly saline types, there is considerable lack of uniformity. In the determination of soil pH by the hydrogen electrode ratios of 1 : 3 and 1 : 5 (soil to water) are employed, most reports favoring the latter. One would anticipate that the less water used the nearer would be the approach to actual soil conditions, and it is this point which adds to the value of the quinhydrone electrode. Most reports favor a 1 : 1 ratio where this method is used.

Dilution (increase in water to soil ratio) lowers the buffer action of the soil, increases ionization and hydrolysis of salts and acids, and therefore a decrease in hydrogen ion concentration. The quinhydrone attains equilibrium almost instantly. Occasionally there will be some "drift." This is usually due to the presence of

some substance which disturbs the equilibrium, and this is the principal limitation to the method.

$$C_6H_4O_2H_2 = C_6H_4O_2 + H_2$$

Extensive applications of the method have shown that such soil types have not often been met. Out of a set of seventy-five soil samples employed by Biilman himself, nearly all agreed within .1 pH, seven cases exceeded .2 pH, which is considered ample precision for soil work. The quinhydrone usually gave higher results, but was also often lower than the hydrogen electrode. Recent investigations indicate that a ratio of 1 : 1 for the quinhydrone electrode agrees with a 1 : 5 ratio as determined by the hydrogen electrode. No description of the soil types which show lack of agreement is given.

To give the method a trial on Hawaiian soils, twenty-two widely varying chemical and physical types were chosen with a reaction range of 4.6 to 8.0.

1. A reddish yellow clay loam from Kaneohe district on Oahu.
2. A blackish silty clay loam from Grove Farm, Kauai.
3. A yellowish brown silty clay loam from Lihue Plantation Company.
4. A yellowish silty clay loam from Kilauea Sugar Plantation Company, Kauai.
5. A brown silt loam from Honokaa Sugar Company, Hawaii.
6. A chocolate brown silt loam from Wahiawa, Oahu—a highly manganiferous type.
7. A heavy clay, blackish gray, valley soil from Oahu.
8. A highly organic silty loam from Olaa Sugar Company, Hawaii.
9. A yellow silty clay loam from Kilauea Sugar Plantation, Kauai.
10. A brown silty clay loam from Kilauea Sugar Plantation, Kauai.
11. A yellow silty clay loam from Kilauea Sugar Plantation, Kauai.
12. A red silty clay loam from Kilauea Sugar Plantation, Kauai.
13. A highly organic silty soil from Hawaiian Agricultural Company, Hawaii.
14. A reddish brown silty clay loam from Kilauea Sugar Plantation Company, Kauai.
15. A red clay loam from Waialua Agricultural Company, Limited, Oahu.
16. A brown silty clay loam from Ewa Plantation Company, Oahu.
17. A yellowish brown silty clay loam from Kilauea Sugar Plantation Company, Kauai.
18. A highly saline soil from the Pearl Harbor District, Oahu.
19. A red clay loam, Oahu Sugar Company, Oahu.
20. A red clay loam, Oahu Sugar Company, Oahu.
21. A red clay loam, Oahu Sugar Company, Oahu.
22. A red clay loam, Oahu Sugar Company, Oahu.

Air dry soil samples were used in all cases, and only boiled, distilled water was used in making the soil-water suspensions. Determinations were made on ratios of 1 : 1, 1 : 3, and 1 : 5, with both electrodes. The results are given in the following table, and graphically in Figs. 1, 2 and 3.

TABLE I

Soil No.	Hydrogen Electrode			Quinhydrone Electrode		
	1 : 1	1 : 3	1 : 5	1 : 1	1 : 3	1 : 5
1	4.63	4.65	4.75	4.38	4.81	4.86
2	4.83	4.76	4.95	4.73	5.05	5.03
3	4.88	4.92	5.14	4.80	5.15	5.24
4	4.93	5.14	5.22	4.73	5.22	5.37
5	5.19	5.48	5.61	5.41	5.54	5.58
6	5.61	5.82	6.05	7.28	7.46	7.72
7	4.97	5.76	6.23	6.10	6.26	6.71

8	5.31	5.78	5.68	5.66	5.87	5.83
9	5.42	5.76	5.91	5.68	5.79	5.83
10	5.47	5.76	5.98	5.75	5.92	5.92
11	5.81	6.19	6.37	6.08	6.26	6.30
12	6.12	6.39	6.44	7.20	7.63	...
13	6.32	6.25	6.74	6.60	6.66	6.68
14	6.66	6.79	6.88	6.72	6.85	6.88
15	6.66	6.86	7.15	7.88	8.14	8.06
16	6.96	6.90	7.05	7.16	7.31	7.38
17	6.57	6.88	7.10	6.76	6.96	6.97
18	7.50	7.71	8.01	7.79	8.00	8.14
19	7.81	7.50	7.67	8.02	8.27	8.36
20	7.38	7.42	7.50	8.36	8.48	8.54
21	7.34	7.52	7.45	8.11	8.44	8.36
22	7.25	7.34	7.08	8.11	8.31	8.36

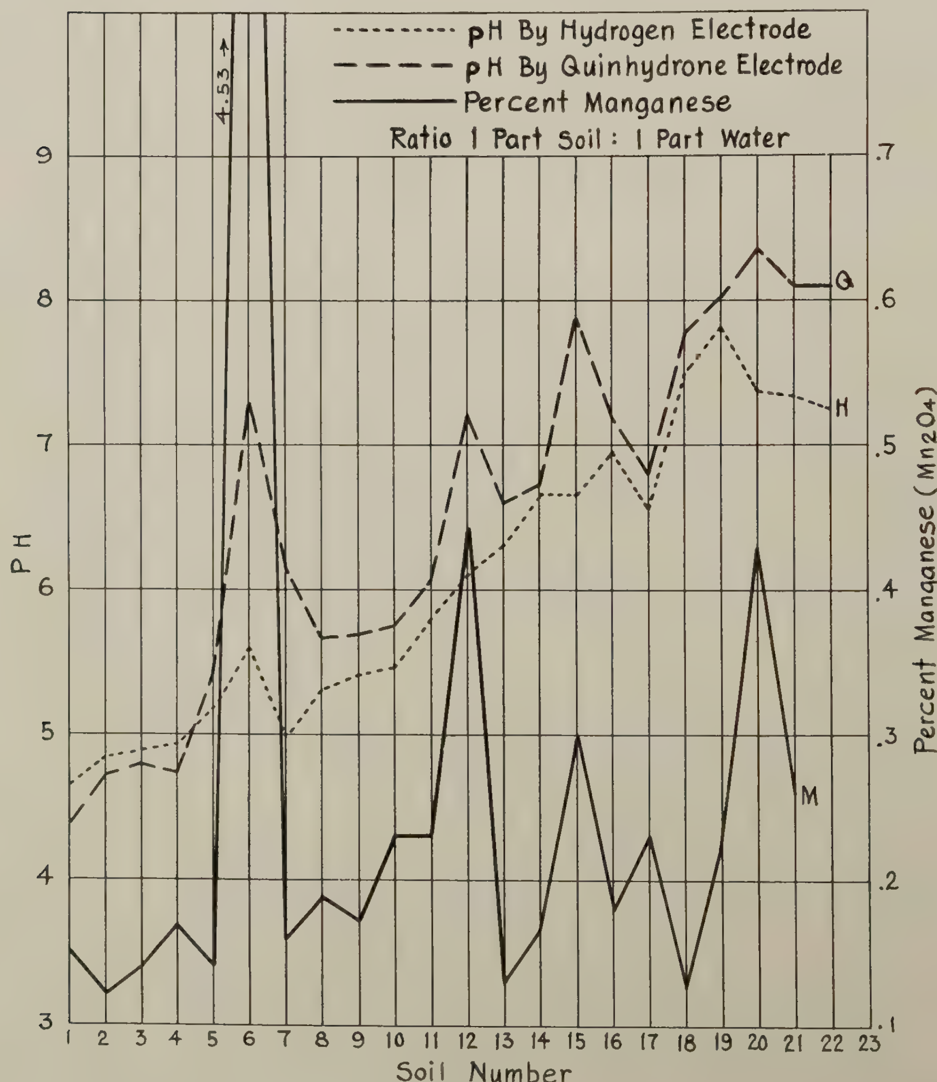

Fig. 1

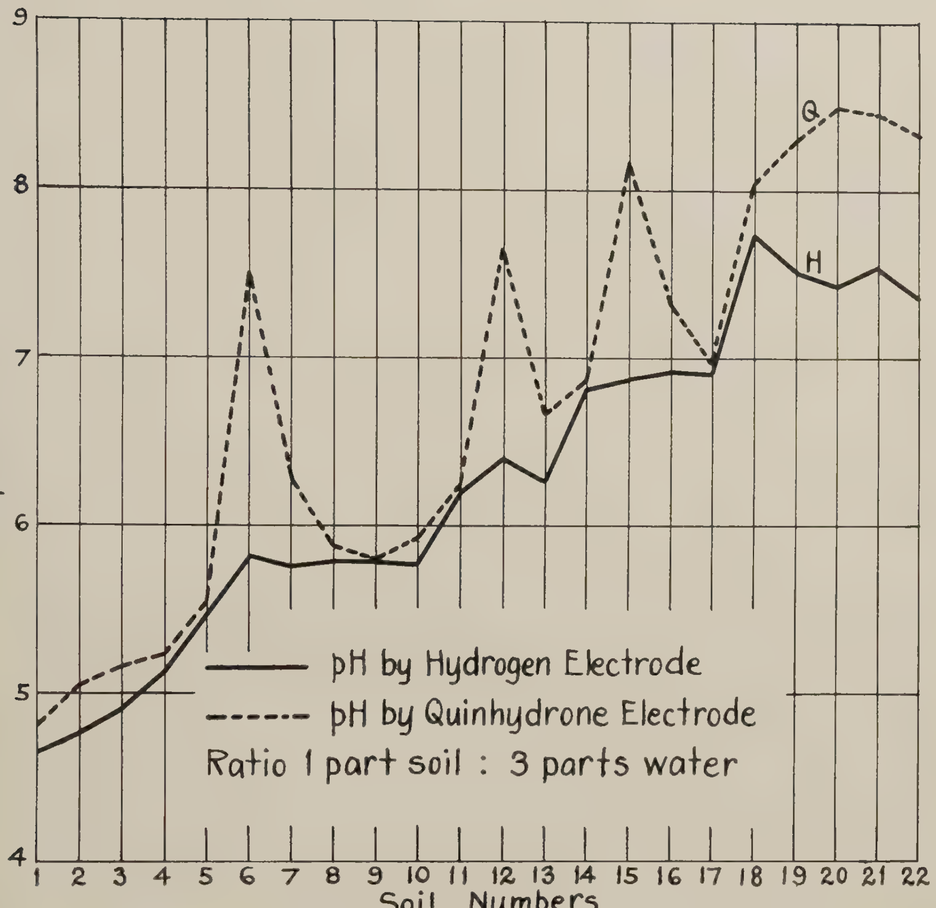

Fig. 2

Hydrogen Electrode

The data in Table I show a consistent decrease in hydrogen ion concentration with dilution. It appears, therefore, that 1 : 1 ratio more nearly approaches the actual hydrogen ion concentration of the soil. On the other hand, in most cases the differences are within the range of precision allowed for soil analyses. On account of the high absorptive power of many Hawaiian soils for water, it is difficult to get a reading with the hydrogen electrode with a 1 : 1 ratio. And even where the mixture is of sufficient fluidity, the potential is very slow in coming to equilibrium. Soils 7 and 8 are samples of this type. Only one set of readings was taken with this series, and this one hour after preparing the soil-water suspension. For the 1 : 3 and 1 : 5 ratios, readings were taken immediately, one hour after preparation, and five hours after. These results are given in the following table :

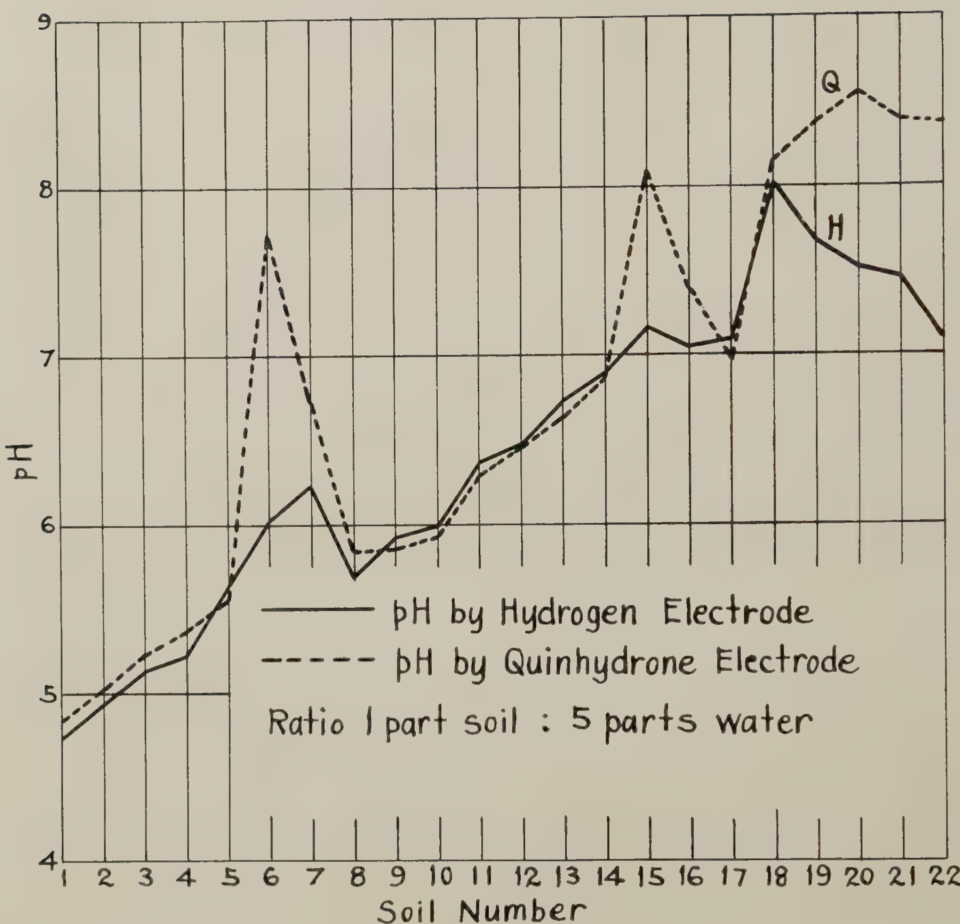

Fig. 3

TABLE II

Soil No.	1:3 Immediate	1:3 1 Hour	1:3 5 Hours	1:5 1 Hour	1:5 5 Hours
1	...	...	...	4.75	4.60
2	4.85	4.76	4.68	4.95	4.94
3	5.02	4.92	4.88	5.14	5.12
4	5.17	5.14	5.09	5.22	4.99
5	5.54	5.48	5.48	5.61	5.58
6	5.71	5.58	5.58	6.05	5.76
7	5.78	5.76	5.68	6.23	6.19
8	5.80	5.78	5.56	5.68	5.68
9	5.88	5.76	5.73	5.91	5.86
10	5.88	5.76	5.78	5.98	5.92
11	6.27	6.19	6.15	6.37	6.25
12	6.45	6.39	6.34	6.44	6.41
13	6.68	6.24	6.57	6.74	6.71
14	6.88	6.79	6.74	6.88	6.88
15	7.00	6.86	6.86	7.15	7.10
16	7.06	6.90	6.83	7.05	6.96
17	7.12	6.88	7.05	7.10	7.05
18	7.79	7.71	7.70	8.01	8.00

These figures show a gradually increasing concentration of hydrogen ion or acidity on standing, and indicate an acid of low solubility or slow rate of hydrolysis.

Quinhydrone Electrode

For the quinhydrone electrode, the soil-water suspensions were prepared one hour in advance, but the quinhydrone added immediately before the determination. Quinhydrone was added at the rate of .025 gram, the whole well shaken, and the reading taken at once. Another .025 gram was then added and another reading taken, this being continued until the reading was constant. That is, until there was no further drift in the potentiometer reading. In most cases .025 gram was sufficient to give the correct and final reading, but in others, notably the manganiferous type, considerably larger amounts were required.

The data obtained by the two methods are of more than passing interest. Sample No. 6 was chosen on account of its high manganese dioxide content. This soil. and also Nos. 12 and 15, gave notably higher pH values by the quinhydrone than by the hydrogen electrode. In view of this, the manganese content of all the soils in the series was determined by extraction with strong HC1 (Sp. Gr. 1.115). These results are given in Table III, along with the readings showing the drift in the potentiometer readings, and graphically in Fig. 1.

TABLE III

Gms. Quinhydrone..		.025	.050	.075	.100	.200
Soil No.	Per Cent* Mn_3O_4	(Potentiometer Reading—E. M. F.)				
1	.05	.160	.160	.160	...	...
2	.02	.174	.174	.174	...	...
3	.04	.180	.180	.180	...	...
4	.07	.185	.185	.185	...	...
5	.04	.203	.203	.203	...	...
6	4.53	.170	.200	.250	.280	.315
7	.06	.255	.272	.275	...	...
8	.09	.222	.222	.222	...	...
9	.07	.217	.218	.218	...	...
10	.13	.225	.225	.225	...	...
11	.13	.245	.245	.245	...	...
12	.34	.295	.325	.325	...	...
13	.03	.267	.269	.269	...	...
14	.07	.280	.280	.280	...	...
15	.20	.335	.350	.356	...	...
16	.08	.307	.307	.307	...	...
17	.13	.286	.286	.286	...	...
18	.03	.347	.347	.347	...	...

It will be noted that the soils containing as little as 0.34 and 0.20 per cent oxides of manganese have high potentiometer readings with the quinhydrone electrode. In order to study this point, further manganese dioxide was added to two soils which showed no potentiometer drift to determine what the effect would be. These results are given in the following table and in Fig. 4. They closely correlate the drift characteristic of the three "truant" soils met in the series under study.

* Weighed and expressed as per cent Mn_3O_4 but largely present in the soil as MnO_2.

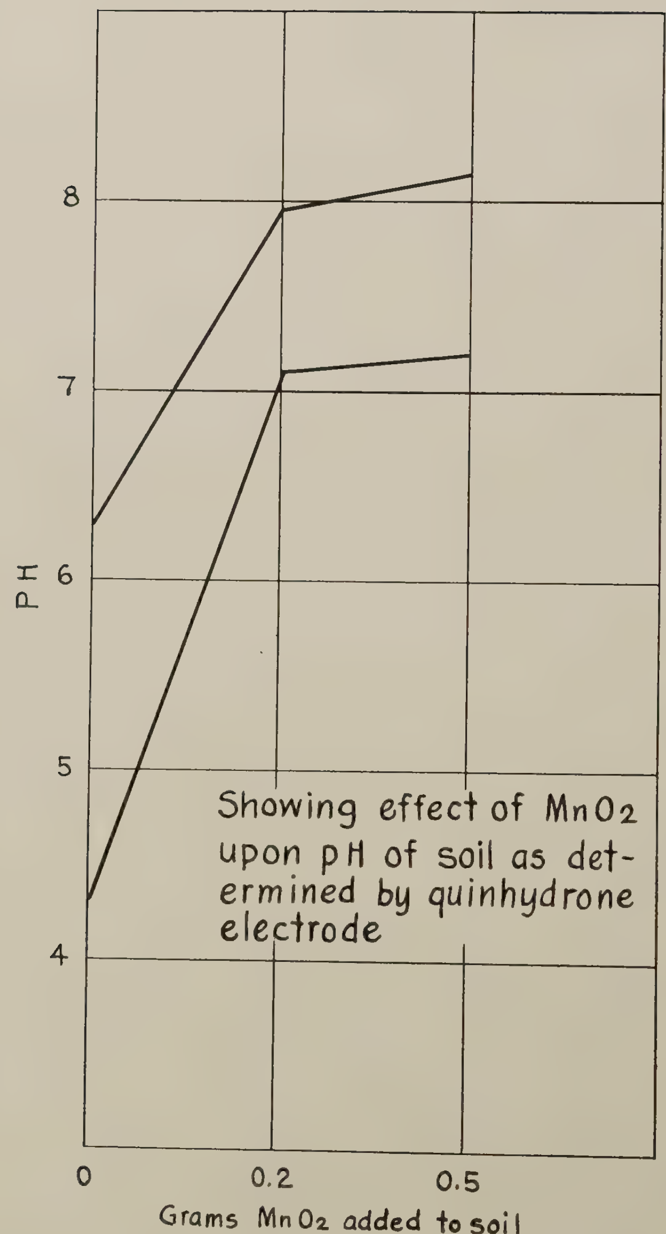
8
7
pH 6
5
4
0
0.2
0.5
Showing effect of MnO_2 upon pH of soil as determined by quinhydrone electrode
Grams MnO_2 added to soil

Fig. 4

TABLE IV

Potentiometer Readings, E. M. F.

MnO_2 Added	Gms. Quinhydrone	Gms. Quinhydrone	Gms. Quinhydrone	
None	.130	.130	.130	Soil No. 1
.2 gm.	.180	.290	.295	
.5 gm.	.230	.295	.300	
None	.245	.245	.245	Soil No. 2
.2 gm.	.295	.345	.345	
.5 gm.	.320	.360	.355	

The question arising from the above contradiction is, which of the two methods is correct? The conclusion seems inevitable that the quinhydrone electrode is in error if applied to Hawaiian soils containing as little as 0.2 per cent manganese dioxide. This would include most of the red clay loams and red silty loams.

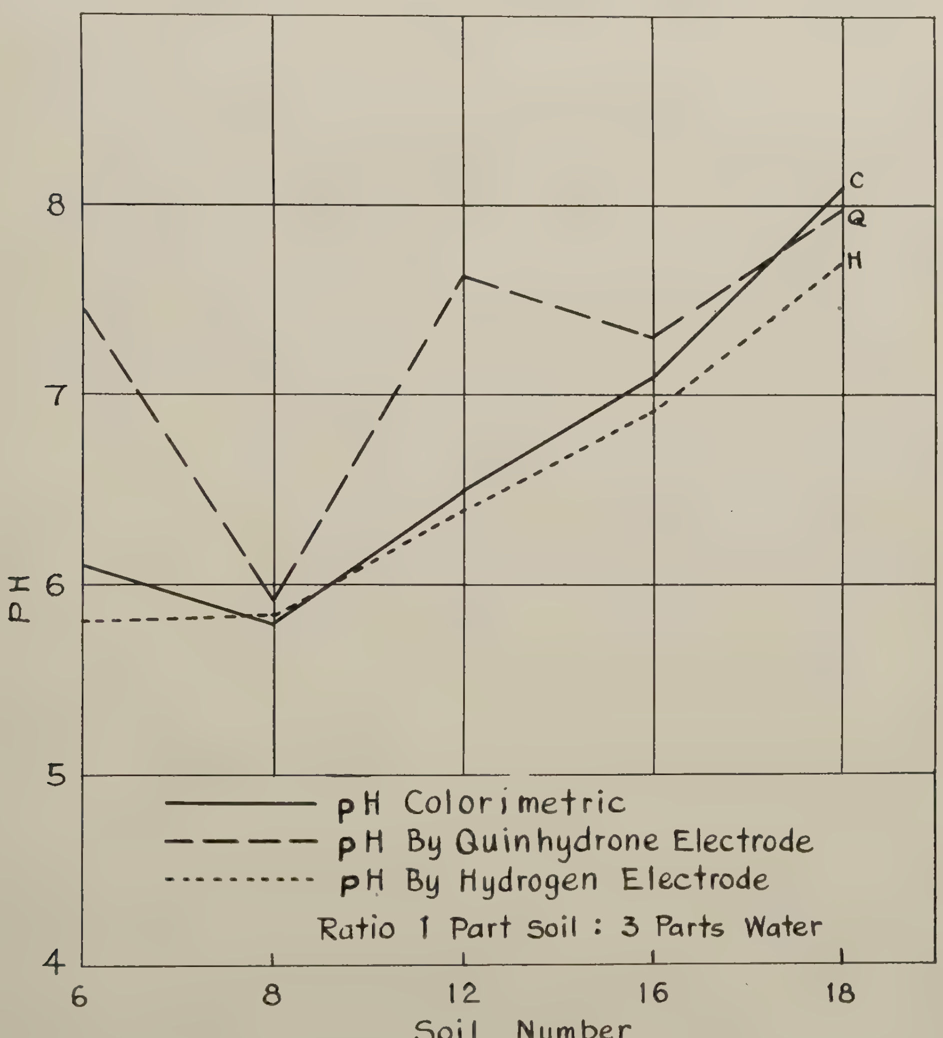

Fig. 5

The colorometric method of determining soil pH values is little influenced by the factors which introduce errors into the quinhydrone and hydrogen electrode methods. It is, however, limited by the difficulty in obtaining a clear water extract without resorting to filtration. Out of the twenty-five soils employed in this investigation, only five would settle sufficiently to give a clear supernatant liquor. The soil pH was therefore determined colorometrically on these five soils. The data compared with the pH as determined electrometrically are shown graphically in Fig. 5. Agreement of all three methods on the nonmanganiferous soils and disagreement on the manganiferous types is shown. Addition of manganese dioxide to these soils and repeating colorometrically and with the hydrogen electrode showed no change in pH values.

Conclusion

The quinhydrone electrode has only limited application for determining the pH values of Hawaiian soils. The presence of manganese dioxide is shown to be a limiting factor and when present in as small amounts as .2 per cent will give high pH values.

In other soil types there is excellent agreement, and in such types the quinhydrone electrode has the advantage in that it is more applicable to a 1 : 1 soil water ratio which most closely approaches the soil water ratio *in situ*. The drift shown by the potentiometer with manganiferous soils is, however, so characteristic as to warn the analyst of the error and thus guards against the reporting of erroneous results. If the potentiometer reading with .05 gram quinhydrone is much higher than with .025 gram, or if the addition of the first .025 gram the potentiometer drifts rapidly downward on standing and before adding the second .025 gram, the soil is unquestionably sufficiently manganiferous to give an error in the reading.

The Terms "Superphosphate" and "Acid Phosphate"

The following letter has been received from The National Fertilizer Association, Washington, D. C.:

Subject: You are asked to use the term "Superphosphate (Acid Phosphate)" instead of "Acid Phosphate."

You will recall that the fertilizer conference which was held at Louisville, Kentucky, September 29 and 30, 1927, upon call of a group of editors of farm papers, and which was attended by agronomists, control officials and members of the industry, voted to refer to the Committee on Definition of Terms of the Association of Official Agricultural Chemists the selection of a less sales-resistant name for acid phosphate. At this conference the name "superphosphate" was preferred.

When the A. O. A. C. held its convention in Washington, October 31 to November 2, 1927, the recommendation of the Committee on Definition of Terms favoring superphosphate with acid phosphate in parentheses, was tentatively adopted, permitting the immediate general use of "Superphosphate (Acid Phosphate)."

The Board of Directors of The National Fertilizer Association at its meeting in Atlanta, November 7, 1927, voted unanimously in favor of ''Superphosphate (Acid Phosphate).'' The words in parentheses will be used only during the transition period and will then be dropped.

The reasons underlying the strong sentiment in favor of a new name for acid phosphate are numerous. In 1842, Sir John Lawes applied the name superphosphate to the product resulting from rendering phosphorus in bones and in phosphatic rock available for plant food by treating them with sulphuric acid. He then, and always thereafter, applied the name superphosphate to the resulting product. With the exception of the United States, it has become the international, world-wide term.

In the early days of fertilizer use in this country, the name superphosphate prevailed, but in some way we fell into the use of the term acid phosphate. In recent years, coincident with the expansion of fertilizer use in new territory, the name acid phosphate has met with a well-defined sales resistance among farmers who naturally have a feeling against all things acid. Many fertilizer manufacturers are adopting ''Superphosphate (Acid Phosphate)'' immediately. For uniformity and for the general good of agriculture, it is highly desirable that everyone change to this less sales-resistant form.

H. P. A.

Annual Synopsis of Mill Data—1927

By W. R. McAllep and W. L. McCleery

The 1927 Synopsis contains data for factory operation at all plantations in the Association for the calendar year ending approximately September 30th. These data represent the production of 802,306 tons of sugar. Instances where this calendar year has not coincided with the crop year are shown in the large table, appropriate marks indicating portions of the 1926 crop ground in this period and unfinished 1927 crops.

Data are presented in much the same form as in previous seasons. Factories are listed in the tabulations in the order of the average size of the five preceding crops, except where otherwise noted. The large table is intended as a compilation of polarization rather than sucrose data, though in the last few years it has been necessary to include sucrose data in a few instances where polarization has not been reported. This year, all factories having reported polarization data, no sucrose data are included in the large table except sucrose in final molasses. Sucrose data are again compiled and averaged in a separate table, Number 7. pH and turbidity data are included in the large table. This is the first time these data have been reported from a sufficient number of factories to be included in the Synopsis.

It appears desirable to discuss the significance of small changes in Synopsis averages from season to season because of differences of opinion on this subject. Comments based on relatively small differences in averages of polarization data have been made frequently in the text of the Synopsis and the question has been raised as to whether the figures are of sufficient accuracy for these small changes to be of significance. Also whether small changes in the averages reflect general tendencies or comparatively large differences in results at a few factories.

Mathematically the figures may be considered correct. Data submitted are carefully checked and somewhat elaborate precautions are taken to insure accuracy in calculating and compiling the tables. While errors sometimes occur in handling a large mass of figures even when careful precautions are taken, so far as we are aware very few such errors have occurred in Synopsis figures in the last few years.

From the standpoint of absolute accuracy the figures are not all that might be desired. Available analytical methods are indirect, and within certain limits data must be considered comparative rather than absolute. These differences from the absolute of course result in a corresponding error in the averages, in fact study of these averages gives considerable information on the size of basic errors in factory control methods. For the purpose of studying factory work, however, we are not concerned with the absolute but rather with the comparative accuracy of the averages; that is, to what extent they are comparable from season to season. As a whole, instruments in use and the laboratory personnel do not change to any great extent from year to year. Brix hydrometers are a possible

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

	H 109	Y. C.	D 1135	Yellow Tip	Striped Tip	Lahaina	Striped Mexican	Others
H. C. & S. Co.	97	..	..	..	..	..	2	1
Oahu	85	..	14	..	..	..	..	1
Ewa	99	..	..	..	..	..	..	1
Waialua	87	5	7	..	..	..	..	1
Maui Agr.	81	..	..	..	..	10	9	..
Olaa	..	87	13	..	..	..	..	..
Pioneer	86	..	1	..	..	1	10	2
Haw. Sug.	73	3	21	..	..	..	..	3
Lihue	58	22	..	7	..	..	..	13
Onomea	..	85	2	12	..	..	..	1
Honolulu	94	5	1	..	..	..	..	..
Hilo	..	92	6	2	..	..	..	..
Kekaha	66	..	12	..	..	21	..	1
Haw. Agr.	..	41	43	..	..	..	3	13
Hakalau	..	81	1	18	..	..	..	..
Wailuku	80	..	5	..	..	6	6	3
Makee	76	9	..	8	..	..	..	7
Honokaa	3	2	85	..	5	..	..	5
McBryde	71	21	3	..	..	..	2	3
Laupahoehoe	..	38	18	44	..	..	..	..
Hamakua	..	37	52	11	..	..	..	..
Kahuku	88	12	..	..	..	..	..	..
Pepeekeo	..	98	1	1	..	..	..	..
Paauhau	4	3	85	5	..	..	..	3
Honomu	..	96	2	..	..	..	..	2
Koloa	61	14	2	18	..	..	..	5
Waiakea	..	97	2	1	..	..	..	..
Hutchinson	..	60	21	..	..	..	..	19*
Hawi	6	..	38	1	47	..	3	5
Kaiwiki	..	24	20	22	7	..	..	27†
Kohala	1	7	39	14	30	..	..	9
Waianae	100	..	..	..	..	..	..	..
Waimanalo	93	3	3	..	..	..	..	1
Kilauea	13	17	6	42	4	..	..	18‡
Kaeleku	..	100	..	..	..	..	..	..
Union Mill	..	1	21	19	58	..	..	1
Halawa	..	15	25	..	60	..	..	..
Niulii	..	33	30	23	14	..	..	..
Waimea	86	..	..	..	..	14	..	..
Olowalu	78	..	..	..	..	..	22	..
True Average 1927	53.1	23.7	11.8	4.0	1.6	1.4	1.3	3.1
" " 1926	48.7	25.6	12.1	4.5	2.1	1.5	1.5	4.0
" " 1925	42.7	30.7	11.9	2.7	2.1	3.1	2.0	4.8
" " 1924	38.1	32.6	12.0	2.3	2.0	4.4	2.5	6.1
" " 1923	30.7	36.3	11.2	1.2	1.6	8.4	3.1	7.5
" " 1922	21.1	40.3	12.2	2.7	1.6	12.0	2.8	7.3
" " 1921	15.0	45.1	11.0	1.2	1.8	17.4	3.0	5.5
" " 1920	9.1	42.7	10.0	1.4	2.1	26.7	2.5	5.5
" " 1919	6.8	46.4	7.2	0.3	2.6	29.1	1.8	5.8
" " 1918	4.0	42.9	7.5	0.5	1.5	37.9	0.6	5.1

* Rose Bamboo.
† Principally D 117.
‡ Principally Badila.

exception, but even in this case practically all of the hydrometers are calibrated in the same laboratory. Based on a rather conservative estimate of the number of determinations made in a season and the probable size of errors made by men of the class carrying on the work in the laboratories, the usual mathematical methods indicate that the probable error in averages in the large table, due to these factors, does not exceed a few units in the third decimal place. It seems safe to state that differences from season to season due to changes in instruments or in personal error do not have a sensible influence on most of the Synopsis averages.

While factors just discussed should not influence the second decimal place, other factors can have such an influence. Such are, for example, the introduction of new analytical methods, the inclusion of data for the Petree Process, a change such as that at H. C. & S. where the mud was discharged from process at the Kopke separators in 1926 and this season returned to the mill. These can influence averages in the second and even the first decimal place. Such factors are not apparent as a rule on casual examination of the figures. Erroneous deductions may be drawn, however, if allowance is not made for their influence. In so far as possible the influence of all such factors is estimated and taken into consideration in writing the text of the Synopsis. Also before making comments on a particular average, changes at individual factories are tabulated. Examination of this tabulation indicates whether the change in the average reflects a general trend or comparatively large changes at a few factories. The result of this examination is stated when this seems necessary or desirable.

We consider that even small changes in the second decimal place, when data are analyzed as described above, are of considerable significance. While data are analyzed with sufficient care so that statements in the text may be considered substantially correct, deductions drawn from these statements are, to some extent, in the nature of opinions, with which it is entirely possible the reader may not agree. The tables in the Synopsis are prepared with the object of presenting data in as convenient form as possible for reference and analysis. In addition to showing results secured and the trend of factory practice, these data can serve in many instances as a basis of studying the chemical control and the effect of changes in operating methods, averages from year to year for a number of factories affording information that can hardly be secured in any other way. The text is an analysis of the data, written largely for the benefit of readers who cannot spare the time involved in making the necessary comparisons. It can also serve as a starting point for more thorough study of details than is practicable in preparing the Synopsis as a whole, particularly with respect to calling attention to factors influencing the comparative accuracy of the averages, which, if left out of consideration, might result in erroneous conclusions. Without doubt the Synopsis might be greatly improved. In the last year or two we have had the benefit of a number of criticisms and suggestions, several of which have been found practicable and have been incorporated in the Synopsis. Any criticism or suggestions to the end that the Synopsis be made more useful will always be welcome.

Varieties of Cane

The distribution of the major varieties of cane by plantations and the ratio of individual varieties to the total crop for the past ten seasons are shown in Table 1.

The percentage of H 109 has increased to 53.1, a figure more than double that of its nearest competitor, Yellow Caledonia. This is the first time in a considerable number of years that over a half of the cane tonnage has consisted of a single variety. Percentages of all the other major varieties are lower than in 1926. Yellow Caledonia, Striped Tip, Lahaina and Striped Mexican have definitely decreased. However, when the biennial nature of the crop is taken into consideration, an increase is indicated for Yellow Tip instead of the decrease indicated by comparison with 1926 only, and D 1135 is about holding its own. Fluctuations in the proportion of D 1135 during the past eight years have been remarkably small.

The five leading varieties are in the same relative positions as last year. Lahaina, in seventh place last year, has decreased slightly less than Striped Mexican, displacing this variety from sixth place. Rose Bamboo, ranking eighth last year, made up less than one per cent of the crop and so has been dropped from the major variety classification. It now ranks third among the minor varieties.

MINOR VARIETIES

One per cent or more of the crop at any factory

Variety	1924	1925	1926	1927
Badila	.46	.35	.47	.37
U. D. 1	...	...	...	.32
Rose Bamboo	...	...	...	.32
D 117	.49	.52	.15	.25
H 456	...	.11	...	.21
Uba	.03	.11	.10	.13
Kohala Seedlings	...	...	.07	.08
H 20	...	.10	...	.04
W 4	...	...	.02	.04
W 2	...	...	...	.03
H 146	.51	.26	.14	...
Yellow Bamboo	.02	.14	.03	...

Badila continues to hold first place among the minor varieties, though the margin is small. Two new seedlings, Wailuku 2 and U. D. 1, appear for the first time. U. D. 1 has been spread with remarkable rapidity. It is now second in the minor variety classification, with a tonnage amounting to .32 per cent of the total crop, although it is but five years since it was propagated from seed. White Bamboo and H 227 have been dropped from this table, as they have not been reported for two years.

Quality of Cane

Data in Table 2 indicate that the cane has been poorer in quality than in any previous year. On the basis of tons of cane required to make a ton of sugar as

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1918					
Polarization	11.88	14.25	13.50	12.54	12.97
Per cent Fiber	13.35	11.53	12.23	12.84	12.50
Purity 1st Expressed Juice	87.27	88.62	86.93	85.88	87.18
Quality Ratio	9.27	7.73	8.27	8.60	8.47
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Per cent Fiber	13.07	11.74	12.14	12.61	12.49
Purity 1st Expressed Juice	87.54	88.81	87.00	85.82	87.34
Quality Ratio	8.66	7.25	7.81	8.20	8.05
1920					
Polarization	12.86	15.29	13.75	13.07	13.64
Per cent Fiber	13.36	11.39	12.65	12.72	12.64
Purity 1st Expressed Juice	87.87	88.94	85.40	86.52	87.24
Quality Ratio	8.45	7.08	8.07	8.28	8.00
1921					
Polarization	12.25	14.67	13.72	12.67	13.12
Per cent Fiber	13.28	11.82	12.40	13.28	12.80
Purity 1st Expressed Juice	87.18	87.37	85.46	84.07	86.22
Quality Ratio	8.98	7.51	8.11	8.76	8.41
1922					
Polarization	12.07	13.95	13.61	13.03	12.97
Per cent Fiber	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.19	7.75	8.04	8.36	8.45
1923					
Polarization	12.09	13.61	12.99	12.94	12.78
Per cent Fiber	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.12	7.91	8.50	8.42	8.57
1924					
Polarization	12.44	14.34	13.48	13.34	13.26
Per cent Fiber	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.86	7.58	8.16	8.12	8.25
1925					
Polarization	12.35	14.42	13.52	13.24	13.22
Per cent Fiber	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.92	7.47	8.18	8.21	8.28
1926					
Polarization	12.53	14.66	13.40	13.03	13.24
Per cent Fiber	12.90	12.24	12.72	12.46	12.65
Purity 1st Expressed Juice	87.59	89.03	86.61	86.68	87.45
Quality Ratio	8.80	7.40	8.29	8.39	8.30
1927					
Polarization	11.34	14.00	12.61	12.07	12.32
Per cent Fiber	12.84	11.98	12.29	12.65	12.49
Purity 1st Expressed Juice	86.27	87.85	85.87	85.17	86.28
Quality Ratio	9.81	7.76	8.86	9.19	8.99

indicated by quality ratio, the decrease in quality corresponds to an increase of almost three-quarters of a ton over that required to make a ton of sugar in 1926, and two-fifths of a ton over that required in 1923; the year which previously held the record for poor cane quality.

The average cane polarization has decreased .92, and the first expressed juice purity 1.17 in comparison with last year. This year's polarization is .46 lower than the previous low point reached in 1923. A slightly lower first expressed juice purity was recorded in one previous season, 1921.

Considering the Islands separately, we find that in each case polarizations and purities are lower and quality ratios higher than in 1926. On Hawaii, Oahu, and Kauai, quality ratios are the poorest on record. On Maui, the quality ratio was poorer in one previous year, 1923.

Data for fiber indicate decreases on Hawaii, Maui, and Oahu, but an increase on Kauai. The average fiber for the crop has decreased .16 in comparison with last season.

Considering data for individual plantations we find that all have reported lower cane polarization and all except one lower first expressed juice purity and poorer quality ratio. Two-thirds of the plantations have reported lower fiber in the cane.

Figures for tons cane per acre for the whole crop and for the five leading varieties are in the following table. These are based on Acreage Census and Annual Synopsis data. Analysis of the discrepancies between these two sets of data indicate that the figures given for tons per acre are probably accurate to within a few tenths of a ton.

TONS CANE PER ACRE

	1925	1926	1927
Crop	53.3	54.4	58.9
H 109	69.4	69.1	73.7
Yellow Caledonia	44.8	45.0	45.1
D 1135	49.3	46.4	46.7
Yellow Tip	41.0	39.8	36.9
Striped Tip	31.5	37.0	30.6

According to the above figures the increase of 4.5 tons of cane per acre for this crop is attributable to heavier yields and larger areas of H 109 and not to an increase in the tonnage of other varieties. Tonnage figures for Striped Tip fluctuate considerably from year to year. Rather than being of general significance these fluctuations reflect conditions in the Kohala district of Hawaii, as some 90 per cent of the Striped Tip is in this district.

Chemical Control

Data for reactions of hot limed juice, clarified juice, and syrup, expressed in terms of pH are included in the Synopsis for the first time. Previously no definite data on juice reactions have been available. The only figure in factory reports having any bearing on this subject has been the amount of lime used. Differences in the amount of lime used in settlings, in the evenness of the liming, in

TABLE NO. 3

True Averages of All Factories Except Those Now Using the Petree Process

	1922	1923	1924	1925	1926	1927
Cane—						
Polarization	12.77	12.66	13.08	12.99	12.99	12.05
Fiber	13.03	12.91	12.82	12.80	12.71	12.55
Tons per ton sugar	8.76	8.68	8.40	8.45	8.50	9.24
Bagasse—						
Polarization	1.71	1.53	1.52	1.54	1.58	1.50
Moisture	41.31	41.29	41.26	41.25	41.09	41.61
Fiber	56.23	56.48	56.74	56.55	56.64	56.20
Polarization % cane	0.40	0.35	0.34	0.35	0.35	0.33
Pol. % pol. of cane	3.11	2.76	2.63	2.69	2.73	2.77
Milling loss	3.05	2.71	2.68	2.73	2.79	2.66
Weight % cane	23.16	22.84	22.59	22.63	22.44	22.33
First Expressed Juice—						
Brix	18.23	17.99	18.34	18.14	18.24	17.17
Polarization	15.79	15.61	16.07	15.91	15.88	14.74
Purity	86.58	86.77	87.61	87.67	87.05	85.84
"Java ratio"	80.9	81.1	81.4	81.7	81.8	81.7
Mixed Juice—						
Brix	13.26	13.11	13.37	13.44	13.65	12.88
Polarization	11.07	11.00	11.31	11.38	11.48	10.67
Purity	83.50	83.87	84.56	84.67	84.12	82.88
Weight % cane	111.65	111.95	112.66	111.03	110.10	109.71
Polarization % cane	12.38	12.31	12.74	12.64	12.64	11.71
Extraction	96.89	97.24	97.37	97.31	97.27	97.23
Extraction ratio	0.24	0.21	0.21	0.21	0.21	0.22
Last Expressed Juice—						
Polarization	1.96	1.73	1.84	1.90	2.06	1.88
Purity	68.66	68.48	71.73	69.63	68.72	67.76
Maceration % cane	34.99	34.79	35.30	33.66	32.54	32.04
Syrup—						
Brix	63.11	63.33	63.18	63.63	64.21	62 91
Purity	84.81	85.40	86.02	85.95	85.49	84.54
Increase in purity	1.31	1.53	1.46	1.28	1.37	1.66
Lime used % cane	0.081	0.085	0.086	0.078	0.083	0.076
Press Cake—						
Polarization	1.96	2.20	2.16	2.17	2.49	2.22
Weight % cane	2.49	2.45	2.45	2.45	2.63	2.67
Polarization % cane	0.05	0.05	0.05	0.05	0.07	0.06
Pol. % pol. of cane	0.38	0.43	0.40	0.41	0.50	0.49
Commercial Sugar—						
Polarization	96.88	96.88	97.20	97.23	97.29	97.40
Moisture	0.85	0.80	0.73	0.74	0.66	0.64
Weight % cane	11.41	11.53	11.91	11.83	11.77	10.83
Polarization % cane	11.06	11.17	11.58	11.50	11.45	10.55
Pol. % pol. of cane	86.94	88.37	88.76	88.78	88.41	87.96
Pol. % pol. of juice	89.69	90.86	91.16	91.24	90.95	90.45
Deterioration factor	0.27	0.26	0.26	0.27	0.24	0.25
Final Molasses—						
Weight % cane	3.14	2.96	2.83	2.82	2.94	3.02
Sucrose % cane	1.07	0.99	0.97	0.93	0.99	1.01
Sucrose % pol. of cane	8.33	7.79	7.45	7.20	7.63	8.37
Sucrose % pol. of juice	8.60	8.01	7.65	7.40	7.84	8.60
Gravity solids	87.94	88.54	89.08	90.09	89.59	89.43
Gravity purity	38.60	37.68	37.81	36.97	37.62	37.40
Undetermined Losses—						
Polarization % cane	0.21	0.11	0.14	0.16	0.13	0.11
Pol. % pol. of cane	1.28	0.65	0.76	0.92	0.73	0.41

the characteristics of different juices with respect to lime requirement and development of acidity, as well as differences in the amount of available CaO in the lime itself, render any inferences based on the amount of lime used most unsatisfactory. Definite data for reaction, expressed as pH values, mark a distinct advance in factory control methods.

The use of pH values brings up the question of how these data should be averaged; that is, whether the figure reported as the average pH should be the average of the pH determinations, or whether it should be the pH corresponding to the average hydrogen ion concentration. After critical examination, in connection with available clarification and control data, we consider that for factory control purposes it is preferable to average pH determinations directly, and pH averages in this Synopsis have been calculated in this way.

Thirty factories have reported pH data. Through a misunderstanding the pH of the cold instead of the hot limed juice has been reported from several factories. These figures have been included in the large table, but have been marked to indicate that they refer to the cold limed juice. They are probably between .1 and .3 higher than if the determinations had been made on the juice after heating. On account of the influence of these figures, this column in the large table has not been averaged.

Turbidity data for clarified juice, determined with the Kopke turbidimeter, are also included for the first time. These data have been reported from 23 factories. In this case also there is some question as to how the averages should be handled, as turbidimeter readings are not in proportion to the amount of suspended matter causing turbidity. Averaging the determinations directly, however, gives a figure which is satisfactory for our purpose and this method of averaging has been used.

Sucrose data have been reported from one additional factory. However, one factory previously reporting sucrose data did not do so this season, leaving the total number the same as in 1926. The thirty factories reporting sucrose data produced 87 per cent of the crop. Gravity solids and sucrose balances for factories reporting the necessary data are in Table 6. Table 7 is a compilation of sucrose data, with true averages for the last two seasons.

There has been no change in the number of factories weighing and measuring the mixed juice. Thirty-six factories report juice weights. The remaining four report weights calculated from mixed juice measurements. Final molasses is weighed at 27 factories, the same number as last season. One additional factory has measured final molasses, bringing the number of factories reporting molasses weights based on measurements to ten. This leaves but three factories reporting neither weights nor measurements.

The usual calculations of recovery on available are in Tables 4 and 5. True sucrose figures in Table 5 should be considered of the greater significance when factories are listed in both tables. During the past few years Synopsis data have reflected a tendency toward higher recoveries on available. This tendency has continued through the past season. Very few low figures are now reported. For instance, there are but four factories reporting under 97 per cent in Table 4 and but three in Table 5. Twenty-three factories report 100 per cent or more on

TABLE NO. 4

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent polarization actually obtained.

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical†
H. C. & S. Co.	92.03	92.71	100.7	91.9
Oahu	91.00	92.74	101.9	90.2
Ewa	91.24	91.64	100.4	88.6
Waialua	91.86	90.93	99.0	82.0
Maui Agr.	91.79	92.55	100.8	96.0
Olaa	90.79	90.40	99.6	95.7
Pioneer	91.28	92.04	100.8	90.2
Haw. Sug.	93.24	94.62	101.5	101.8
Lihue	89.71	91.74	102.3	84.7
Onomea	91.00	91.96	101.1	88.3
Honolulu	89.81	89.23	99.4	86.7
Hilo	91.61	92.29	100.7	90.9
Kekaha	89.75	89.09	99.3	92.8
Haw. Agr.	89.58	89.52	99.9	91.0
Hakalau	91.21	92.10	101.0	89.5
Wailuku	90.91	91.36	100.5	92.2
Makee	87.53	89.27	102.0	87.6
Honokaa	88.93	89.72	100.9	91.8
McBryde	91.09	91.25	100.2	94.9
Laupahoehoe	91.78	90.02	98.1	76.5
Hamakua	92.16	91.28	99.0	90.8
Kahuku	90.38	91.40	101.1	84.6
Pepeekeo	91.59	92.10	100.6	91.1
Paauhau	89.83	88.93	99.0	96.5
Honomu	91.53	91.92	100.4	89.3
Koloa	89.71	91.17	101.6	92.2
Waiakea	88.15	87.48	99.2	94.0
Hutchinson	89.58	86.20	96.2	92.4
Hawi	88.56	89.01	100.5	93.7
Kaiwiki	91.07	90.04	98.9	101.4
Kohala	91.19	90.66	99.4	101.0
Waianae	85.88	83.12	96.8	80.7
Waimanalo	88.82	90.74	102.2	83.6
Kilauea	85.54	85.98	100.5	90.0
Kaeleku	85.09	85.30	99.7	81.0
Union Mill	88.21	90.04	102.1	84.7
Halawa	89.56	89.90	100.4	....
Niulii	88.96	87.29	98.1	....
Waimea	89.88	86.80	96.6	....
Olowalu	90.66	83.40	92.0	69.1

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained	% Recovery on Available	Molasses Produced on Theoretical*
H. C. & S. Co.	92.05	92.07	100.0	91.3
Oahu	91.00	91.84	100.9	84.8
Ewa	91.36	90.56	99.1	89.4
Waialua	91.86	89.75	97.7	86.5
Maui Agr	91.97	92.00	100.0	98.4
Pioneer	91.32	91.27	99.9	89.2
Haw. Sug	93.41	93.57	100.2	99.0
Lihue	89.96	90.44	100.5	80.4
Onomea	91.21	91.68	100.5	90.0
Honolulu	90.32	87.73	97.1	94.8
Hilo	91.31	92.18	101.0	87.5
Haw. Agr	89.80	88.45	98.5	91.5
Hakalau	91.31	91.49	100.2	89.2
Wailuku	90.93	90.76	99.8	91.5
Makee	87.62	88.33	100.8	84.4
Honokaa	88.92	89.35	100.5	95.2
McBryde	91.08	90.68	99.6	96.2
Laupahoehoe	91.28	89.88	98.5	72.5
Hamakua	92.00	91.03	98.9	97.9
Kahuku	90.48	90.34	99.8	83.4
Pepeekeo	91.37	91.88	100.6	89.2
Paauhau	89.74	88.54	98.7	99.2
Honomu	91.55	91.48	99.9	88.9
Koloa	89.62	90.55	101.0	88.1
Waiakea	88.25	86.92	98.5	98.6
Hutchinson	89.44	85.67	95.8	104.8
Waianae	86.24	82.51	95.7	90.3
Waimanalo	88.75	90.14	101.6	77.9
Kilauea	85.75	84.86	99.0	89.8
Olowalu	90.16	82.16	91.1	84.7

* Calculated by the S. J. M. formula.

available in Table 4, against a previous maximum of twenty. Nine of these report over 101 per cent. Thirteen factories report 100 per cent or more in Table 5, against a previous maximum of eleven. One factory only is over 101 per cent in Table 5. There is considerable evidence that much of this general tendency toward higher recovery on available reflects an actual improvement in the work due to closer attention to details in the boiling house, particularly with respect to juice reactions. The accompanying increase in the number of factories reporting in excess of 100 per cent on available has focused attention on several small discrepancies in our control methods. As these have been discussed at some length in the last few Synopses, it does not seem necessary to go into details at this time. However, we would point out that because of these discrepancies the calculated figure for available sucrose is less than the amount of sucrose actually available and that probably slightly in excess of the calculated amount can be recovered in factory practice. Due consideration must be given this factor in analyzing factory operating data. Though data now available are not sufficient to define exactly how much the calculated figure is depressed, it is probably not in excess of one per cent on a true sucrose basis. The instance where over 101 per cent recovery on available has been reported in Table 5 may be considered as due to errors in the control. The nine instances in Table 4 may be considered strongly indicative of such errors.

Tables 4 and 5 also contain data for molasses produced on the theoretical. In Table 4, the theoretical is assumed to be the differences between gravity solids in the syrup and solids accounted for in the sugar. The S. J. M. formula is used for calculating the theoretical in Table 5. Both calculations are valuable for the analysis of control data. Comparisons of the two sets of figures are also of interest, for in the absence of discrepancies in control data differences between them should not be large.

When these molasses calculations were first included in the Synopsis in 1921, the figures were very inconsistent. From year to year since that time there has been an improvement both in the extent to which the less consistent figures vary from the average and in the number of figures varying considerably from the average. This year the average for molasses produced on the theoretical is 91.2; a figure slightly higher than in 1926. A majority of the factories report higher figures than last season.

The deficiencies in control methods, which depress the calculated figure for available sucrose, increase the calculated figure for the theoretical amount of molasses to a considerably greater extent. Averages for molasses produced on the theoretical for the past five years, calculated on the basis of gravity solids in syrup less solids accounted for in the sugar, are between a minimum of 89.2 and a maximum of 91.2 with an average for the five years of 90.5. No doubt conditions at individual factories cause some variation in the amount of molasses produced on the theoretical, but it does not seem as if these variations should be very large, say not in excess of five on each side of the average for all factories. Assuming tentatively that figures for individual factories should be within five of 91.2, the average for this season, we find four factories in Table 4 above and

nine below these limits. It seems reasonably certain that the three high figures indicate errors in control and the low figures, control errors, undetermined losses or both.

Gravity solids and sucrose balances for factories reporting sucrose data are in Table 6. No negative undetermined loss of solids has been reported. One factory has reported a negative undetermined loss of sucrose; an indication of chemical control errors.

A number of comments, based on figures for undetermined loss, have been made in recent Synopses. As opinions on the significance of these figures differ considerably, a discussion of this subject seems desirable.

The undetermined loss purports to be the difference between sugar in the cane and sugar accounted for. Actually it refers to boiling house work only, for up to the time the juice is weighed any factors that would influence it, alter instead the figure for cane polarization. On a sucrose basis the undetermined loss represents mechanical and chemical losses in addition to those determined and reported separately, and the algebraic sum of control errors. On a polarization basis it includes the influence of two other factors. The loss in molasses is reported as sucrose instead of polarization and the ratio of polarization to sucrose is higher in the sugar than in the mixed juice. In both instances the basis on which the sugar is accounted for is relatively higher than the basis on which it is determined in the mixed juice. These factors then depress the undetermined loss below the actual value.

As noted above, the undetermined loss includes the sum of control errors. Weights and analyses are not of absolute accuracy. Just what should be considered a reasonable limit for the sum of unavoidable errors cannot be stated definitely. However, as these errors should be more or less compensating, and mechanical and chemical losses are always sustained to some extent, it seems reasonable to consider a negative undetermined loss on a sucrose basis as evidence of larger than unavoidable control errors. Examination of available data indicates that on a polarization basis figures for undetermined loss are some .5 to 1.0 lower than on a sucrose basis. It is quite probable that a small negative undetermined loss may be indicated by polarization figures in the absence of larger than what may be considered unavoidable errors in the chemical control.

In analyzing data for a single factory, conclusions based on changes in the undetermined loss must be drawn conservatively for such factors as the personal error in weights and analyses, the accuracy of scales, etc., are liable to differ sufficiently from season to season so that this figure is modified by more than a negligible amount. In the case of averages of data from say 40 factories, however, the influence of such factors becomes extremely small and the undetermined loss figure assumes considerable significance. For example, several times in recent years there have been fairly definite indications that boiling house operations have been carried on at more alkaline reactions. Experimental work has shown that this decreases inversion velocities. Under such circumstances a reduction in the Synopsis average for undetermined loss, after examining data to define other factors which might have influenced it, may be considered corroborative evidence that a reduction in inversion loss has been realized.

TABLE NO. 6
GRAVITY SOLIDS AND SUCROSE BALANCES

Factory	Gravity Solids per 100 Gravity Solids in Mixed Juice				Sucrose per 100 Sucrose in Mixed Juice			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	0.1	82.4	16.1	1.4	0.01	92.09	7.26	0.64
Oahu	5.0	76.4	16.5	2.1	0.64	91.24	7.64	0.48
Ewa	5.6	74.0	17.7	2.7	0.42	90.20	7.72	1.66
Waialua	4.8	75.5	15.6	4.1	0.46	89.33	7.04	3.17
Maui Agr.	...	81.1	18.2	0.7	....	92.00	7.90	0.10
Pioneer	4.4	75.7	17.7	2.2	0.28	90.97	7.74	1.01
Haw. Sug	4.0	80.6	15.4	...	0.40	93.16	6.52	0.08
Lihue	4.1	73.3	18.6	4.0	0.63	89.91	8.08	1.38
Onomea	4.9	75.5	18.0	1.6	0.16	91.51	7.91	0.42
Honolulu	5.0	72.3	19.6	3.1	0.58	87.22	9.18	3.02
Hilo	4.2	77.3	16.9	1.6	0.33	91.85	7.60	0.22
Haw. Agr.	4.3	73.8	19.8	2.1	0.42	88.14	9.63	1.81
Hakalau	4.2	75.8	18.0	2.0	0.14	91.41	7.76	0.69
Wailuku	3.9	76.6	17.8	1.7	0.39	90.41	8.29	0.91
Makee	4.6	70.7	21.4	3.3	0.59	87.82	10.43	1.16
Honokaa	6.3	70.7	21.3	1.7	0.48	88.95	10.05	0.52
McBryde	3.8	76.0	19.2	1.0	0.23	90.49	8.58	0.70
Laupahoehoe	3.3	77.7	14.4	4.6	0.21	89.66	7.05	3.08
Hamakua	...	80.4	17.8	1.8	....	91.03	7.83	1.14
Kahuku	5.4	71.2	19.5	3.9	0.54	89.83	7.94	1.69
Pepeekeo	6.2	74.1	17.9	1.8	0.28	91.56	7.69	0.47
Paauhau	5.0	72.5	21.5	1.0	0.48	88.15	10.18	1.19
Honomu	4.9	75.7	17.2	2.2	0.24	91.26	7.52	0.98
Koloa	6.5	71.2	20.4	1.9	0.54	90.06	9.14	0.26
Waiakea	5.6	71.3	21.8	1.3	0.67	86.37	11.58	1.38
Hutchinson	6.2	69.6	22.3	1.9	0.24	85.52	11.07	3.17
Waianae	4.1	67.5	23.0	5.4	0.55	82.07	12.38	5.00
Waimanalo	5.3	71.5	19.0	4.2	0.61	89.58	8.76	1.05
Kilauea	3.8	66.2	26.5	3.5	0.86	84.14	12.79	2.21
Olowalu	3.2	67.9	18.8	10.1	0.23	81.96	8.33	9.48

TABLE NO. 7
SUCROSE DATA

Factory	Cane Sucrose*	MIXED JUICE		SYRUP		SUGAR		Undetermined Loss per 100 Sucrose* in cane
		Sucrose	Gravity Purity	Gravity Purity	Increase in Purity	Sucrose	Sucrose per 100 Sucrose* in cane	
H. C. & S. Co.	14.64	12.40	88.20†	85.21	0.01	97.78	89.67	0.64
Oahu	12.94	11.52	85.21	86.35	1.14	98.11	88.95	0.47
Ewa	12.84	11.10	83.46	85.24	1.78	97.97	88.58	1.63
Waialua	13.23	11.54	85.48	87.00	1.52	97.84	87.05	3.08
Maui Agr.	14.74	12.32	86.88†	87.29	0.41	97.90	89.42	0.10
Pioneer	13.80	12.06	84.34	85.45	1.11	97.94	88.74	0.98
Haw. Sug.	14.45	12.71	87.53	88.38	0.85	97.89	90.71	—0.08
Lihue	11.48	11.21	82.06	83.00	0.94	97.45	87.39	1.35
Onomea	10.99	9.22	83.82	85.40	1.58	97.92	90.18	0.42
Honolulu	13.47	11.33	84.81	86.70	1.89	100.0	84.58	2.93
Hilo	11.29	9.91	84.70	85.98	1.28	97.51	89.97	0.22
Haw. Agr.	11.36	11.40	84.07	85.58	1.51	97.57	85.01	1.74
Hakalau	11.32	9.63	83.89	84.86	0.97	97.29	90.24	0.68
Wailuku	13.57	10.96	85.49	86.30	0.81	97.95	88.86	0.89
Makee	10.69	9.68	82.24	82.70	0.46	97.62	84.07	1.12
Honokaa	10.10	9.43	81.22	83.01	1.79	97.81	85.17	0.50
McBryde	12.95	11.17	84.75	85.74	0.99	97.81	87.62	0.67
Laupahoehoe	12.27	10.05	87.09	87.95	0.86	97.62	87.02	3.08
Hamakua	12.62	11.97	86.68†	87.16	0.48	97.51	88.45	1.11
Kahuku	10.82	9.59	80.86	82.09	1.23	97.91	87.80	1.65
Pepeekeo	11.24	10.09	82.70	84.68	1.98	97.83	89.41	0.46
Paauhau	10.69	9.33	82.86	84.59	1.73	97.69	85.90	1.16
Honomu	11.62	9.80	83.76	85.70	1.94	97.91	89.49	0.97
Koloa	11.49	10.47	80.79	83.00	2.21	98.07	87.10	0.26
Waiakea	11.60	10.65	83.27	85.11	1.84	97.15	82.41	1.31
Hutchinson	10.96	10.88	84.21	85.05	0.84	97.67	81.63	3.03
Waianae	13.08	11.25	82.36	83.49	1.13	97.35	79.46	4.84
Waimanalo	11.10	9.47	80.46	82.25	1.79	97.54	87.87	1.03
Kilauea	10.42	9.84	79.48	79.87	0.39	97.77	81.39	2.14
Olowalu	13.53	11.74	83.26	83.64	0.38	96.93	80.16	9.28
‡True Average 1927	12.46	11.01	84.53	85.86	1.33	97.79	87.96	1.13
" " 1926	13.35	11.68	85.38	86.66	1.28	97.67	88.41	1.20

* Polarization in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane.
† Clarified juice.
‡ Refinery data from Honolulu not included in averages.

Milling

No new milling machinery installations have been reported this season.

The comparatively large changes in cane quality must be taken into account when comparing mill data with that of last year. With an average cane polarization .92 lower than last year, offset to but a slight extent by a decrease of .16 in the average fiber, it has been necessary to reduce the bagasse to a materially lower polarization to obtain extraction figures approximately those of last season. The changes in cane quality have been quite general.

The average grinding rate is 47.87 tons of cane per hour, an increase of 1.44 over 1926. Although 60 per cent of the factories report higher grinding rates the average tonnage ratio has not increased. With the same tonnage ratio as last year and lower fiber in the cane, the average tonnage fiber ratio has decreased from 22.48 to 22.24. The apparent discrepancy of an increase in the average grinding rate without a corresponding increase in tonnage ratio is because most of the decreases in grinding rates have been at factories with comparatively short rollers, where a given change in grinding rate influences the tonnage ratio to a greater extent than where the rollers are longer. Data from Maui Agricultural Company, a large factory with comparatively short rollers, account for a considerable part of the apparent discrepancy. One tandem was operated at very high capacity at this factory during a considerable portion of the 1926 crop while the other tandem was under construction. With both tandems in operation in 1927 the tonnage ratio was reduced .54, an amount sufficient to make a change of several hundredths in the crop average.

Data for pressure per foot of roller indicate an increase from 67.4 to 68.2 tons. A tendency toward higher pressure has been evident for several seasons.

The tendency toward lower maceration which also has been evident for a number of years has continued. The decrease is from 33.61 to 32.53.

Referring to data for factories which do not use the Petree Process, we find that the difference in purity between first expressed and mixed juice has increased slightly; 2.93 to 2.96. On the other hand, the difference between first expressed and last expressed juice purities has been reduced from 18.33 to 18.08.

Bagasse data indicate an increase of .3 in moisture and a decrease of .19 in fiber. These changes, tending toward an increase in bagasse per cent cane, have been more than offset by the decrease in cane fiber, resulting in a reduction of .22 in the weight of bagasse per cent cane. Bagasse polarization has been reduced from 1.62 to 1.53 and milling loss from 2.88 to 2.73. These averages for bagasse polarization and milling loss are lower than in any previous season except 1921. From the standpoint of extraction, reductions in bagasse per cent cane and in bagasse polarization have not been quite sufficient to offset lower cane polarization, with the result that the average extraction is .02 lower than last year. Although the decrease in the average extraction is small, the tendency toward lower extraction has been quite general. Twenty-five factories report lower extraction against 11 reporting higher.

Considering the milling work as a whole, we find that a slightly smaller proportion of the total sugar in the cane has been extracted. On the other hand,

TABLE NO. 8—MILLING RESULTS

Showing the Rank of the Factories on the Basis of Milling Loss.

Rank	1926 Rank	Factory	Milling Loss	Extraction Ratio	Extraction	Maceration	Tonnage Ratio	Tonnage Fiber Ratio*
1	1	Hakalau......	1.17	0.11	98.70	36.20	1.63	20.15
2	2	Onomea.......	1.26	0.12	98.53	38.86	1.91	24.39
3	3	Waimanalo....	1.65	0.15	98.06	37.45	1.96	23.48
4	4	Hilo..........	1.70	0.15	97.95	35.44	1.80	24.50
5	7	Honomu.......	1.83	0.16	98.06	37.75	1.48	18.16
6	10	Kahuku.......	1.91	0.18	97.71	31.81	1.60	20.42
7	8	Ewa..........	1.98	0.16	98.18	34.91	1.73	20.09
8	6	Wailuku.......	1.99	0.15	98.27	41.88	1.16	13.54
9	5	Kekaha.......	2.00	0.15	98.21	28.87	1.77	20.48
10	11	Olowalu.......	2.05	0.16	97.78	36.09	1.66	23.66
11	12	Paauhau......	2.09	0.20	97.42	33.92	1.09	14.16
12	9	Pepeekeo......	2.11	0.19	97.63	29.66	1.68	21.05
13	15	Hamakua......	2.49	0.20	97.16	28.21	1.46	20.89
14	26	Lihue.........	2.55	0.23	97.15	22.80	2.06	26.06
15	13	Oahu..........	2.61	0.20	97.45	32.11	1.86	23.21
16	23	Waialua.......	2.65	0.20	97.41	34.16	2.22	28.31
17	17	Kilauea.......	2.66	0.26	96.68	26.21	1.47	18.86
18	16	Pioneer.......	2.76	0.20	97.52	35.43	2.18	26.77
19	20	Koloa.........	2.80	0.25	96.68	30.34	1.41	18.99
20	21	Laupahoehoe..	2.81	0.23	97.04	40.64	1.66	21.31
21	32	Hawi.........	2.93	0.24	96.74	32.51	1.71	22.86
22	19	Haw. Sug.....	2.97	0.21	97.34	33.14	1.50	19.17
23	18	McBryde......	3.02	0.24	96.79	36.19	1.20	16.37
24	27	Kohala........	3.03	0.25	96.94	43.34	1.61	19.43
25	29	Waimea.......	3.14	0.27	96.77	30.87	1.51	18.27
26	25	Olaa..........	3.16	0.26	96.73	30.32	2.17	26.84
27	22	Haw. Agr.....	3.18	0.28	96.40	18.38	1.88	23.84
28	14	H. C. & S. Co.	3.31	0.23	97.35	35.87	1.69	19.65
29	24	Honolulu......	3.43	0.26	96.92	36.39	1.68	19.91
30	30	Waianae......	3.43	0.26	96.77	34.20	1.52	18.56
31	31	Honokaa......	3.43	0.35	95.72	24.11	1.64	20.38
32	38	Maui Agr.....	3.48	0.24	97.17	38.77	1.89	22.47
33	28	Makee........	3.60	0.34	95.67	28.80	2.02	25.57
34	33	Kaiwiki.......	3.78	0.30	96.15	34.02	1.69	21.48
35	35	Waiakea......	3.80	0.33	95.37	30.17	1.52	21.37
36	34	Kaeleku.......	3.95	0.37	95.00	27.98	1.94	26.31
37	36	Hutchinson....	4.10	0.38	95.42	17.05	2.04	24.66
38	40	Niulii.........	5.08	0.47	93.70	24.89	1.73	22.96
39	37	Union Mill....	5.37	0.49	92.96	24.52	1.72	24.89
40	39	Halawa.......	6.10	0.54	92.65	27.37	1.60	21.62

* Tonnage ratio multiplied by per cent fiber in cane.

the loss of sugar per cent fiber in the bagasse, or "milling loss" has been considerably reduced and the mills have been operated at higher capacity. As the loss per cent fiber in bagasse is a better standard for judging the efficiency of mill operation than the per cent of the total sugar extracted, we consider that as a whole the milling has been more efficient than in 1926.

No factory has equaled the records made in previous seasons for extraction, extraction ratio or milling loss. Seven factories report extractions higher than 98.0 and eight factories report milling loss lower than 2.0. In comparison with 1926 this is a decrease of one in the number of factories reporting higher than 98 extraction and an increase of one in the number of factories reporting under 2.0 milling loss.

Table 8 is a condensed summary of milling results in which the factories are listed according to the size of the milling loss. No changes have taken place in the relative positions of the first four factories. Hakalau is again in first place, followed by Onomea, Waimanalo and Hilo. Lihue and Hawi have improved their relative standing by 12 and 11 places respectively. Waialua, Maui Agricultural, Kahuku and Waimea have also improved their standing materially. H. C. & S. has dropped from fourteenth to twenty-eighth place. Other factories ranking materially lower than last year are McBryde, Hawaiian Agricultural Co., Honolulu and Makee.

Boiling House Work

Clarification: Referring to data in Table 3 for factories which do not use the Petree Process, we find a material improvement in the increase in purity from mixed juice to syrup. The average for this season is 1.66 compared with 1.37 for last year and 1.28 for 1925. Twenty-one factories have reported larger against 13 reporting smaller increases. Figures in the large table for pH of the limed juice indicate that on the whole the juice has been limed to a moderately high pH. After deducting the probable difference between pH of the cold and hot limed juice, where the figures reported are for the juice before heating, we find only a few factories actually within the range where experimental work has indicated the maximum increase in purity is secured. Two-thirds of the factories reporting pH values, however, are within .2 and .3 of this range.

The figure reported for lime consumption has been reduced from .081 to .076 per cent cane, the lowest figure since 1921. In view of the fact that liming as a whole is somewhat below the pH range in which the maximum increase in purity is secured, and that in recent years the size of the increase in purity has fluctuated fairly consistently with fluctuations in the amount of lime used, a larger increase in purity with a smaller figure for lime consumption renders a careful study of factors having a bearing on this point of decided interest.

A decrease in the amount of lime used in settlings would have a tendency in this direction, for, provided the total amount does not exceed the requirement of the juice, better clarification can be secured with a given amount of lime if all of it is added to the juice instead of being divided between the juice and settlings. Though figures for lime used in settlings are not very reliable, such data as are

available do not indicate any material change in this practice in comparison with last season, and it does not seem probable that this factor has influenced the relation of lime used to increase in purity.

Solids in the mixed juice, calculated to per cent on cane, are much lower than in 1926. This can hardly be considered an explanation of the point in question, however, as the lime requirement is a function of the impurities rather than the total solids, and impurities in mixed juice per cent cane are actually higher than in 1926.

The comparatively large changes in cane quality this season may have a bearing on this question. In experimental work on clarification different juices have been found to vary greatly in the amount of precipitable impurities and in lime requirement, although no particular correlation has been observed between purity and these factors; that is, either high or low purity juices may give large or small increases in purity and require large or small amounts of lime. The juices referred to, however, were usually from different areas. In juices from cane grown on the same or similar areas, it does not seem improbable that conditions which cause seasonal changes in certain characteristics of the cane, such as purity and juice density, also tend toward differences in the lime requirement and in the amount of precipitable impurities. No definite information on this point is available at present. When pH data covering a number of years have become available it should be possible to define the effect of seasonal changes on clarification.

There are two factors, however, which have tended toward a low figure for lime and a high figure for increase in purity. These are a change in the way lime is reported and closer attention to juice reactions in the factory. At the beginning of the 1926 season, lime figures on the basis of available CaO instead of total lime were requested. A considerable number of factories reported on this basis, rendering the 1926 figure for lime consumption low in comparison with those for previous years. An additional number of factories, though not all, have changed to the available CaO basis this season. Also hydrated lime has been used much more extensively this season, and usually this has been reported on the basis of 65 per cent available CaO, although hydrated lime supplied locally is much nearer 70 per cent available than 65. The 1927 lime figure is thus low in comparison with 1926, and considerably low in comparison with previous years. Attention has been focused to a considerable extent on irregularities in liming during the past few seasons, particularly since pH determinations have been included in the control, and considerable improvement is being made in this respect. Liming to an even pH, provided the amount of lime used does not exceed the lime requirement, will give a better increase in purity with the same amount of lime than if the pH of the juice is irregular.

pH data as previously noted indicate that on the whole the juice has been limed to a fairly high pH. While we have no data on which to base direct comparisons with previous seasons, observations during factory visits give us considerable reason for believing that the pH is higher than in the past. The reduction in undetermined loss is an indication in this direction, as a reduction in inversion losses, tending toward a reduction in the undetermined, should accompany a higher pH in clarification.

The above indicates that the reduction, if any, in the amount of lime used, is less than would be inferred from reported figures. It is also probable that closer attention to juice reaction has brought about more even liming, thus obtaining a higher average pH with a given amount of lime. We consider that the larger increase in purity is because the juice has been limed to a higher pH. Possibly changes in the character of the juice with respect to lime requirement and the amount of precipitable impurities have been contributing factors, but on this point no data are available at the present time.

Although first expressed juice purity is 1.17 lower than in 1926 and the decrease from first expressed to mixed juice purity slightly larger than last season, the larger purity increase in clarification has resulted in a syrup but .91 lower in purity than last year. Better results in clarification have reduced the difference between the first expressed juice and syrup purity from 1.67 to 1.41. This difference is smaller than in any except three of the previous seasons for which averages are available, and approximates the figure attained in these three seasons, 1914, 1918, and 1923. Available data on this point are tabulated below for reference.

PURITY DECREASE—FIRST EXPRESSED JUICE TO SYRUP

1914	1.40	1921	2.32
1915	1.65	1922	1.88
1916	1.52	1923	1.40
1917	1.66	1924	1.54
1918	1.40	1925	1.65
1919	1.64	1926	1.67
1920	2.04	1927	1.41

Filter Presses: Referring to data in Table 3 we find that the polarization of the press cake has been reduced from 2.49 to 2.22 and that the amount of press cake per cent cane has increased from 2.63 to 2.67 per cent. While the polarization is lower than in 1926, it is higher than in any previous year. The amount of press cake is higher than reported in any previous season. As the decrease in polarization is relatively greater than the increase in weight, the loss in press cake has been reduced. Calculated to per cent on cane, the reduction in this loss is moderate, but calculated as a percentage on polarization in cane the loss is but a trifle lower than the high mark reached last season.

The increased amount of press cake has increased the duty on filter press equipment to some extent. On the other hand lower juice densities have rendered it easier to obtain a lower polarization. On the whole the efficiency with which the filter presses have been operated does not seem to differ much from last season.

Additional filter press equipment has been installed at Lihue and Kohala and the Oliver Filter at Oahu was operated for the whole season as against a couple of months only in 1926. The loss in press cake per cent polarization in cane has been reduced approximately .1 at each of these factories.

Evaporation: Additional capacity has again been secured from evaporator equipment. Calculations on the same basis as those in the last few Synopses indicate an increase of 3.2 per cent in the amount of water evaporated per hour and .7 in the percentage of water evaporated on mixed juice. Although the equipment

has been operated at higher capacity, the Brix of the syrup has decreased, due to lower juice densities. This decrease from 64.04 to 63.10, brings the Brix of the syrup to the lowest point in six seasons.

Commercial Sugar: Commercial sugar polarization has increased from 97.30 to 97.40. Higher polarizations at factories shipping sugar to the Crockett refinery have brought about this increase. The average for other factories is slightly lower than last year.

Moisture in the sugar has been reduced from .68 to .65. The reduction in moisture is in slightly greater proportion than the increase in polarization, bringing the deterioration factor down to .250. This is the first time the deterioration factor has been reduced to this point.

Available data on refining qualities of the sugar are tabulated in the report of the Raw Sugar Technical Committee, to which reference is made for these data. We might note, however, that in size of grain the sugar has been poorer than in recent years both with respect to the proportion of the crop and the number of factories above the standard. The quality of the sugar has steadily decreased with respect to size of grain for several years. The filtration rate of sugar shipped to Crockett is somewhat lower than last year, 79.1 against 81.5. Increased grinding rates and lower purities have been factors contributing toward these undesirable changes in refining qualities.

Low Grades: Although higher grinding rates and lower juice purities have imposed additional duty on low grade equipment, the molasses purity has been reduced from 37.97 to 37.59. The tendency toward lower molasses purity can hardly be considered general, as 18 factories report higher against 19 reporting lower and 1 the same. While the average for this season is considerably lower than the 1926 average, lower figures have been reported in three previous seasons. The record made in 1925 is .27 lower than this year's average. After correcting for the change in analytical methods to put the figures on a comparable basis, 1919 and 1923 molasses purities are also lower than this season.

Notwithstanding more efficient low grade work, the influence of lower juice purities has been sufficient to increase the weight of molasses per cent cane from 2.93 to 3.03 and the loss of sucrose in molasses per cent cane from .99 to 1.02. With the additional factor of lower cane polarization, the loss of sucrose per cent polarization of cane has increased from 7.72 to 8.46. This is higher than in any previous year except 1921.

Kahuku has reported an average molasses purity of 31.81, thus establishing a new record. The previous record, 32.46 was made by the same factory in 1925.

Massecuite storage tanks have been replaced by crystallizers at Hamakua with a reduction of 4.59 in molasses purity in comparison with the previous season. A similar change was made at Hutchinson and although the new equipment was not in use the whole of the season an improvement of 1.44 was made in the season's average for molasses purity.

Undetermined Loss: Polarization averages in the large table indicate a reduction of .28 in undetermined loss while sucrose averages in Table 7 indicate a reduction of .07. The impression given by both of these figures is somewhat erroneous. In comparison with last season, the figure for undetermined loss based

on polarization has been depressed by the increase in the amount of molasses. This means that a larger proportion of sucrose (a relatively higher figure than polarization) has been subtracted from polarization in cane. We estimate that this factor has depressed the undetermined loss figure .13 in comparison with last year, basing this estimate on analysis of a large amount of polarization and sucrose data for molasses from practically all factories. Applying this correction, the reduction in undetermined loss based on polarization data becomes .15. On a sucrose basis the figures are influenced by data from Union Mill and Waianae. Union Mill reported .60 undetermined loss on a sucrose basis in 1926, but did not submit sucrose data in 1927. Sucrose data were not reported from Waianae last year, while this season an undetermined loss of 4.84 was reported on this basis. Data from these factories have influenced the sucrose average for undetermined loss to the extent of .04. This makes the corrected sucrose average .11 lower than last season, a figure in reasonably close agreement with the corrected figure of .15 on a polarization basis. With reference to the difference between these corrected figures, we would point out that a number of factories are not included in the sucrose averages. Also examination of polarization and sucrose data indicates that the ratio of polarization to sucrose in mixed juice is slightly lower than last year, while in the sugar this ratio remains unchanged. This factor contributes to the difference in question.

After correcting for the influence of different amounts of molasses, the undetermined loss this season is the lowest since these figures have been averaged.

Recovery

In comparison with last season boiling house recovery has decreased .37 and recovery per cent polarization of cane .36, bringing these figures to the lowest point since 1922. Higher sugar polarization has accounted for .04 of the decrease in recovery. As this does not influence the recovery of available sugar, on this basis we may consider that recovery has decreased .32 instead of the .36 noted above. The decrease in the quality of the juice corresponds to a considerably larger decrease in recovery than that actually sustained. Calculations on the basis of normal juice purity indicate that with the same quality of work as last season, the recovery would be depressed 1.09 instead of .32, thus indicating that when data are calculated to a comparable basis, an improvement over the work of last season corresponding to some .77 in recovery has been realized. Three factors account for the major part of this improvement. Larger increases in purity in clarification are equivalent to something in excess of .3 in recovery. Lower molasses purity is equivalent to between .15 and .2. Assuming that lower figures for undetermined loss reflect actual reductions in such losses rather than control errors, between .1 and .15 is accounted for in this way.

In summing up the season's work we find that the cane has been materially lower in quality. The chemical control has been improved through the inclusion of pH determinations and turbidity figures. There are also indications of improvement in the accuracy of the figures from year to year. Factories have been operated at higher capacity. There are indications that milling has been more

TABLE NO. 9

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

Recovery % Calculated Recovery *					Recovery % Recovery Indicated by "Sugar Ratio" †	
Rank	Factory	Milling	Boiling House	Over All	Rank	Over All
—	Kahuku	97.71	103.76	101.74	—	101.18
1	Hakalau	98.70	101.96	100.79	1	100.25
—	Waimanalo	98.06	102.38	100.73	—	100.53
—	Lihue	97.15	103.17	100.66	—	99.88
—	Onomea	98.53	101.68	100.44	—	100.50
—	Koloa	96.68	102.45	99.61	—	98.73
2	Ewa	98.18	101.03	99.51	3	99.61
3	Pepeekeo	97.63	101.73	99.49	4	99.29
4	Pioneer	97.52	101.29	99.33	6	98.76
5	Honomu	98.06	100.94	99.25	5	98.77
—	Haw. Sug.	97.34	101.54	99.04	—	99.68
6	Hilo	97.95	100.49	98.74	2	99.67
—	Oahu	97.45	100.92	98.70	—	99.27
7	Maui Agr.	97.17	100.72	98.36	8	98.01
8	Wailuku	98.27	99.53	98.09	7	98.38
9	H. C. & S. Co.	97.35	99.89	97.63	9	97.69
10	McBryde	96.79	100.14	97.27	10	97.45
11	Kilauea	96.68	99.71	96.96	17	95.97
12	Honokaa	95.72	100.74	96.92	19	95.82
13	Kekaha	98.21	98.21	96.90	11	96.74
—	Makee	95.67	100.72	96.78	—	94.96
14	Hamakua	97.16	98.80	96.43	16	96.02
15	Hawi	96.74	99.17	96.43	18	95.93
16	Waialua	97.41	98.48	96.23	12	96.65
17	Paauhau	97.42	98.19	96.05	13	96.61
18	Honolulu	96.92	97.18	95.50	14	96.18
19	Kohala	96.94	98.00	95.42	15	96.16
20	Olaa	96.73	98.27	95.39	20	95.48
21	Haw. Agr.	96.40	98.32	95.13	21	95.01
22	Laupahoehoe	97.04	96.45	93.86	22	94.40
23	Kaiwiki	96.15	97.03	93.56	23	93.66
24	Waimea	96.77	95.84	93.05	24	93.07
25	Waiakea	95.37	95.95	92.02	25	91.73
—	Union Mill	92.96	97.98	91.51	—	91.47
26	Kaeleku	95.00	95.93	91.48	27	90.99
27	Halawa	92.65	97.97	91.20	26	91.56
28	Hutchinson	95.42	94.99	91.01	28	90.61
29	Olowalu	97.78	92.52	90.78	30	89.46
30	Niulii	93.70	96.29	90.63	29	89.55
31	Waianae	96.77	92.89	90.17	31	89.29

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses. Factories reporting boiling house recovery in excess of 101% on available (Table 4) are included in the table but no ranking is assigned.

† The basis of this calculation is 98.02 extraction, syrup purity one less than the apparent purity of the first expressed juice, gravity purity of molasses 33.33 and no other losses. In this case also no rank has been assigned when over 101% boiling house recovery on available has been reported.

efficient, though on account of the quality of cane there has been a slight decrease in extraction. The drop in purity from first expressed to mixed juice is slightly less satisfactory than last season. Much better results have been obtained in clarification and slightly better results at the filter presses. Better results have been secured also in the low grade work, notwithstanding the additional duty imposed on equipment by higher grinding rates and lower juice purities. Undetermined losses have been reduced. Control data, calculated to a comparable basis, indicate an improvement corresponding to between .7 and .8 in recovery as the net result of factory operation this season. Comparisons on the basis of quality ratio also indicate an improvement, though smaller than that indicated by control figures. On this basis, after correcting for the difference in sugar polarization, an improvement of .2 per cent is indicated.

Comparison of Actual and Calculated Recoveries

The usual comparisons of actual and calculated recoveries and a ranking of factories on this basis are in Table 9. Complying with suggestions that have been received, figures for all factories are given, but no ranking has been assigned to factories reporting in excess of 101 per cent of the theoretical boiling house recovery in Table 4, instead of omitting them from the table as in previous years. Comparisons on the basis of "sugar ratio," a calculation suggested by Mr. S. S. Peck, are also included in Table 9. Factors assumed in calculating "sugar ratio" are in a footnote under the table. It is identical with "cane ratio," recently adopted by the Association of Hawaiian Sugar Technologists in place of quality ratio, except that the actual instead of an assumed value is used for commercial sugar purity.

Relative standings as calculated by these two different methods are in fairly good agreement in most instances, though there are several rather large discrepancies. These are due principally to the difference in the values assumed for final molasses purity.

In previous Synopses we have expressed the opinion that calculations such as these are of value for giving a good general idea of the quality of the factory work, but that drawing close distinctions on such a basis is not justified. Discrepancies in the results given by these two calculations illustrate this point. Given accurate control data, we consider that a reasonably accurate estimate can be made as to how closely the actual recovery approximates the recovery it is possible to attain with present processes. Such an estimate, however, involves careful analysis of all control data. The various considerations involved are not readily expressed as a mathematical formula. Many formulae purporting to express the efficiency of factory operation as a percentage figure have been proposed. Some of these give a satisfactory approximate idea of the quality of the work, but all that have come to our attention are open to more or less serious objection from the standpoint of accurately defining the efficiency with which operations have been conducted.

Calculations in this Synopsis have been made by Mr. A. Brodie.

ANNUAL SYNOPSIS OF MILL DATA—SHOWING RESULTS FROM 40 HAWAIIAN FACTORIES FOR CROP OF 1927

Factory	Factory No.	Milling Plant (Sizes in Inches)	CANE Polarization	CANE % Fiber	CANE Tons per ton commercial sugar	CANE Tons ground per hour	CANE Tonnage ratio	BAGASSE Polarization	BAGASSE % Moisture	BAGASSE % Fiber	BAGASSE Pol. per 100 cane	BAGASSE Pol. per 100 pol. of cane	BAGASSE Pol. per 100 Fiber ("Milling Loss")	BAGASSE Weight per 100 cane
H. C. & S. Co.**	6	K(4),2RC78(2),S72(2),12RM78(2)	14.49	11.63	7.45	59.47‡	1.69	1.83	42.03	55.34	0.38	2.65	3.31	20.91
Oahu	20	K(2),2RC78(2),S72(2),12RM78(2)	12.78	12.48	8.52	65.52‡	1.86	1.44	42.65	55.25	0.33	2.55	2.61	22.59
Ewa	5	K(2),2RC78,18RM78	12.64	11.61	8.61	85.34	1.73	1.08	43.79	54.49	0.23	1.82	1.98	21.31
Waialua	17	K(2),2RC78,12RM78	13.02	12.75	8.50	78.10	2.22	1.51	40.97	56.88	0.34	2.59	2.65	22.43
Maui Agr.**	21	K(4),3RC66(2),12RM66(2)	14.59	11.89	7.43	47.69‡	1.89	1.84	44.35	52.83	0.41	2.83	3.48	22.50
Olaa	36	K,S72,12RM78	11.89	12.37	9.45	61.21	2.17	1.71	43.40	54.20	0.39	3.27	3.16	22.67
Pioneer	10	K,2RC72,S72,15RM72	13.65	12.28	7.99	78.35	2.18	1.43	45.94	51.66	0.34	2.48	2.76	23.77
Haw. Sug.	16	K,2RC72,S72,12RM78	14.25	12.78	7.47	52.68	1.50	1.69	40.87	56.94	0.38	2.66	2.97	22.45
Lihue	27	K,2RC78,S72,12RM78	11.28	12.65	9.71	72.48	2.06	1.40	42.85	55.00	0.32	2.85	2.55	23.00
Onomea	34	2RC60,S54,12RM66	10.92	12.77	9.88	48.24	1.91	0.75	38.99	59.83	0.16	1.47	1.26	21.35
Honolulu	13	K(2),S54,2RC78,9RM78	13.25	11.85	8.78	47.20	1.68	1.93	41.10	56.21	0.41	3.08	3.43	21.08
Hilo	33	K,2RC60,12RM66	11.24	13.61	9.60	45.48	1.80	0.97	41.56	57.00	0.23	2.05	1.70	23.87
Kekaha	25	2RC54,15RM60	12.98	11.57	8.63	44.27	1.77	1.17	39.51	58.37	0.23	1.79	2.00	19.82
Haw. Agr.††	30	3RC60,12RM66	11.21	12.68	10.11	47.37	1.88	1.81	40.64	56.86	0.40	3.60	3.18	22.30
Hakalau††	7	2RC54,12RM9-60,3-66	11.17	12.36	9.52	33.87	1.63	0.72	37.68	61.30	0.14	1.30	1.17	20.16
Wailuku	2	K,2RC72,12RM78	13.42	11.67	8.10	40.90	1.16	1.16	39.69	58.55	0.23	1.73	1.99	19.93
Makee	14	2RC72,S72,9RM72	10.56	12.66	10.90	48.60	2.02	1.98	42.25	54.96	0.46	4.33	3.60	23.04
Honokaa††	35	K(2),2RC66,12RM66	9.88	12.35	11.55	41.40	1.64	1.83	43.96	53.39	0.42	4.28	3.43	23.13
McBryde	12	K,2RC72,S72,9RM84	12.84	13.64	8.62	39.33	1.20	1.72	40.67	56.94	0.41	3.21	3.02	23.96
Laupahoehoe††	41	K,2RC54,9RM60	12.19	12.84	9.14	27.61	1.66	1.63	39.73	58.10	0.36	2.96	2.81	22.11
Hamakua**	15	K,2RC60,12RM60	12.54	14.31	8.74	30.34	1.46	1.38	42.47	55.49	0.36	2.84	2.49	25.79
Kahuku	43	K,2RC60,S54,9RM72	10.68	12.76	10.31	38.44	1.60	1.13	39.06	59.20	0.24	2.29	1.91	21.55
Pepeekeo	19	2RC54,9RM60	11.16	12.53	9.74	28.01	1.68	1.26	38.36	59.94	0.26	2.37	2.11	20.90
Paauhau	24	2RC60,12RM66	10.59	12.99	10.63	27.45	1.09	1.24	38.91	59.20	0.27	2.58	2.09	21.94
Honomu	37	3RC60,9RM60	11.53	12.27	9.42	24.67	1.48	1.06	40.59	57.84	0.22	1.94	1.83	21.21
Koloa	38	K,2RC60,12RM66	11.38	13.47	9.80	35.60	1.41	1.56	41.84	55.70	0.38	3.32	2.80	24.19
Waiakea	3	K,2RC60,9RM60	11.51	14.06	10.16	25.38	1.52	2.03	43.62	53.48	0.53	4.63	3.80	26.26
Hutchinson††	31	2RC60,9RM60	10.87	12.09	10.91	33.95	2.04	2.38	38.69	58.05	0.50	4.58	4.10	20.86
Hawi	26	K,2RC54,12RM54	11.99	13.37	9.42	28.94	1.71	1.64	41.50	55.96	0.39	3.26	2.93	23.89
Kaiwiki	32	K,2RC60,9RM60	12.50	12.71	9.05	28.18	1.69	2.17	39.77	57.41	0.48	3.85	3.78	22.14
Kohala	40	K(2),3RC60,9RM60	12.16	12.07	9.15	26.92	1.61	1.73	40.78	56.72	0.37	3.06	3.03	21.48
Waianae	9	K,12RM60	12.93	12.21	9.36	25.27	1.52	1.96	40.01	57.24	0.42	3.23	3.43	21.33
Waimanalo	1	K,3RC54,9RM54	10.95	13.00	10.00	26.42	1.96	0.96	40.14	58.34	0.21	1.94	1.65	22.23
Kilauea††	23	K,3RC60,9RM60	10.27	12.83	11.53	24.5	1.47	1.45	43.17	54.50	0.34	3.32	2.66	23.54
Kaeleku	47	K,2RC54,9RM60	10.70	13.56	11.44	32.31	1.94	2.19	41.54	55.45	0.53	5.00	3.95	24.46
Union Mill	11	K,9RM60	11.01	14.47	10.58	21.54	1.72	2.84	43.46	52.84	0.77	7.04	5.37	27.33
Halawa	29	K,2RC60,6RM50	11.22	13.51	10.47	13.89	1.60	3.26	42.33	53.40	0.82	7.35	6.10	25.31
Niulii	39	K,9RM54	10.73	13.27	11.04	17.55	1.73	2.77	41.77	54.52	0.68	6.30	5.08	24.39
Waimea	4	2RC48,12RM42	11.78	12.10	9.87	15.45	1.51	1.85	38.30	58.92	0.38	3.23	3.14	20.54
Olowalu	18	K,3RC48,9RM48	13.26	14.25	8.94	17.77	1.66	1.26	36.62	61.42	0.29	2.22	2.05	23.40
True Average, 1927			12.32	12.49	8.98	47.87	1.78	1.53	41.78	56.00	0.34	2.77	2.73	22.30
" " 1926			13.24	12.65	8.31	46.43	1.78	1.62	41.48	56.19	0.36	2.75	2.88	22.52
" " 1925			13.22	12.74	8.27	45.31	1.71	1.58	41.56	56.18	0.36	2.71	2.82	22.67
" " 1924			13.26	12.74	8.26	43.63	1.62	1.56	41.58	56.19	0.35	2.67	2.78	22.67
" " 1923			12.78	12.82	8.56	42.03	1.56	1.55	41.56	56.18	0.35	2.77	2.76	22.80
" " 1922			12.97	12.95	8.62	39.93	1.54	1.69	41.51	56.05	0.39	3.02	3.02	23.09
" " 1921			13.12	12.80	8.61	36.58	1.40	1.50	41.20	56.58	0.34	2.57	2.64	22.58
" " 1920			13.64	12.64	8.12	39.34	....	1.56	41.05	56.68	0.35	2.55	2.75	22.29
" " 1919			13.74	12.49	7.94	....	....	1.67	41.57	56.05	0.37	2.70	2.97	22.27
" " 1918			12.97	12.50	8.51	....	....	1.59	42.70	55.04	0.36	2.79	2.90	22.74

Factory No.	FIRST EXPRESSED JUICE Brix	FEJ Polarization	FEJ Purity	FEJ Pol. of cane x 100 / Polarization	MIXED JUICE Brix	MJ Polarization	MJ Purity	MJ pH Hot Limed Juice	MJ Weight per 100 cane	MJ Pol. per 100 cane	MJ Pol. per 100 pol. of cane ("Extraction")	MJ Extraction Ratio	LAST EXPRESSED JUICE Polarization	LEJ Purity	MACERATION WATER Weight per 100 cane	MACERATION WATER Dilution % normal juice
6	20.12	17.97	89.31	80.6	14.06	12.27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40.26
20	17.96	15.52	86.41	82.3	13.52	11.37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29.00
5	18.02	15.41	85.53	82.0	13.30	10.93	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31.65
17	18.31	16.02	87.5	81.3	13.50	11.35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32.08
21	20.33	17.96	88.34	81.2	14.18	12.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40.48
36	16.37	14.22	86.9	83.6	12.84	10.68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27.5
10	19.89	17.22	86.58	79.3	14.30	11.92	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36.31
16	18.95	16.83	88.81	84.7	14.53	12.53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.83
27	17.11	14.31	83.6	78.8	13.66	10.98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
34	14.95	12.81	85.71	85.2	11.00	9.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37.32
13	18.40	15.80	85.9	83.9	13.36	11.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35.55
33	15.23	13.11	86.08	85.7	11.70	9.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32.56
25	17.86	15.24	85.3	85.2	14.11	11.69	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26.36
30	16.04	13.84	86.28	81.0	13.56	11.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.64
7	15.43	13.28	86.07	84.1	11.48	9.51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34.41
2	17.98	15.61	86.8	86.0	12.82	10.82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40.95
14	16.37	13.89	84.9	76.0	11.77	9.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
35	15.31	12.93	84.45	76.4	11.61	9.36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26.6
12	18.55	16.01	86.31	80.2	13.18	11.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37.94
41	16.41	14.58	88.9	83.6	11.54	9.98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40.8
15	18.18	16.16	88.89	77.6	13.81	11.89	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31.64
43	16.05	13.27	82.68	80.5	11.86	9.46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31.27
19	15.74	13.54	86.0	82.4	12.20	10.02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27.70
24	15.61	13.15	84.24	80.5	11.26	9.21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32.86
37	15.90	13.87	87.2	83.1	11.70	9.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35.90
38	17.44	14.67	84.1	77.6	12.96	10.37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
3	16.93	14.53	85.82	79.2	12.79	10.56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27.53
31	15.22	13.13	86.27	82.8	12.92	10.78	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15.48
26	18.49	15.56	84.15	77.1	13.22	10.68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.05
32	17.61	15.48	87.90	80.7	12.63	10.74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33.81
40	16.95	14.59	86.08	83.3	11.56	9.67	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43.85
9	19.66	16.65	84.69	77.7	13.66	11.09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33.38
1	16.46	13.59	82.56	80.6	11.77	9.32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35.68
23	15.88	12.72	80.1	80.7	12.38	9.67	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22.54
47	15.98	13.13	82.16	81.5	12.29	9.82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26.60
11	16.4	14.1	86.0	78.1	12.6	10.53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.15
29	16.10	13.68	84.97	82.0	12.25	10.18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28.16
39	15.32	13.09	85.44	82.0	12.20	10.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24.34
4	16.85	14.35	85.16	82.1	12.55	10.33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.20
18	19.50	16.86	86.46	78.6	14.10	11.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35.62
1927	17.52	15.12	86.28	81.53	13.03	10.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1926	18.52	16.20	87.45	81.73	13.68	11.58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1925	18.42	16.19	87.92	81.64	13.60	11.59	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1924	18.51	16.26	87.86	81.55	13.52	11.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1923	18.09	15.75	87.05	81.1	13.13	11.06	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1922	18.44	16.01	86.84	81.0	13.46	11.27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1921	18.74	16.16	86.22	81.2	13.25	10.97	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1920	19.32	16.85	87.24	80.9	13.48	11.31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1919	19.17	16.74	87.34	82.0	13.39	11.29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....
1918	18.26	15.92	87.18	81.3	12.92	10.85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....

Factory No.	CLARIFIED JUICE Purity	CJ pH	CJ Turbidity	SYRUP Brix	SYRUP Purity	SYRUP Increase in Purity	SYRUP pH	PRESS CAKE Polarization	PC Weight per 100 cane	PC Pol. per 100 cane	PC Pol. per 100 pol. of cane	LIME USED (Weight per 100 Cane) In Juice	In Settlings	Total
6	87.28	7.2	3.21	66.18	87.34	0.06	7.3	1.16	0.09	...	0.01	0.07	...	0.07
20	85.44	7.19	...	62.40	85.53	1.43	7.28	2.97	2.73	0.08	0.63	0.05	0.02	0.07
5	83.37	7.31	4.11	67.34	84.20	2.06	7.47	2.20	2.41	0.05	0.42	0.09	0.01	0.10
17	85.7	7.70	3.89	64.26	86.2	2.1	7.37	1.89	3.15	0.06	0.46	0.07		0.07
21	86.04	7.07	5.07	65.71	86.18	0.14	7.00	...	...	...	...	0.09		0.09
36	85.4	7.7	3.9	60.34	85.4	2.2	7.7	4.89	1.77	0.09	0.73	...	...	0.07
10	84.40	7.65	3.25	66.54	84.61	1.25	7.38	1.33	2.86	0.04	0.28	0.06	...	0.06
16	87.09	7.0	3.70	64.73	87.39	1.15	7.0	2.17	2.60	0.06	0.39	0.04	0.01	0.05
27	81.9	...	...	59.14	81.8	1.4	7.4	2.23	3.12	0.07	0.62	...	...	0.08
34	84.18	7.86	3.22	65.76	84.27	1.03	7.42	0.74	2.28	0.02	0.15	0.05	...	0.05
13	86.1	7.1	3.2	63.72	85.3	1.9¶	7.1	2.62	2.92	0.08	0.58			0.07
33	85.40	7.4	3.6	71.06	85.59	1.23	7.2	1.15	3.12	[illegible]	0.32	0.05		0.05
25	83.9	7.73	1.98	60.05	83.9	1.1	7.61	3.37	2.59	[illegible]	0.67	0.09	0.01	0.10
30	84.59	...	...	64.57	84.61	1.65	...	1.59	2.86	0.05	0.41	0.11	...	0.11
7	83.42	7.38	3.02	64.53	83.68	0.84	6.95	0.61	2.63	0.02	0.14	...	...	0.05
2	85.3	7.07	...	65.98	85.4	1.0	6.94	2.05	2.57	[illegible]	0.39	0.10		0.10
14	82.1	...	...	59.63	81.8	0.7	...	2.21	2.75	[illegible]	0.57	0.05	0.02	0.07
35	82.27	7.6	2.6	59.80	82.21	1.59	7.5	1.96	2.34	[illegible]	0.46	0.07	0.01	0.08
12	84.92	...	...	61.62	84.97	0.98	..	1.86	1.58	[illegible]	0.22	0.04	0.05	0.09
41	87.5	7.33	5.42	63.81	87.5	1.0	7.25	1.16	2.21	0.03	0.21	0.05	...	0.05
15	86.10	7.7	...	49.86	86.52	0.42	7.6	...	...			0.07		0.07
43	81.92	7.5	4.57	60.23	81.26	1.46	7.38	1.68	3.46	0.06	0.54	0.07	0.02	0.09
19	83.8	7.8	4.3	69.74	84.1	2.0	7.4	1.27	2.42	[illegible]	0.27	0.07		0.07
24	83.48	7.55	...	66.41	83.69	1.90¶	7.26	1.84	2.74	[illegible]	0.48	0.05		0.05
37	84.5	7.52	...	72.82	84.9	2.0	7.02	1.12	2.53	[illegible]	0.21	0.06	...	0.06
38	81.9	7.1	2.8	60.99	82.3	2.3	7.1	2.06	2.91	[illegible]	0.53	0.09	0.07	0.16
3	83.49	7.54	3.05	49.22	84.27	1.71	7.34	3.12	2.37	[illegible]	0.64	...		0.08
31	84.92	7.46	2.71	64.07	84.36	0.92	7.21	1.06	2.39	[illegible]	0.23	...		0.06
26	81.95	...	..	59.14	82.57	1.79	...	1.98	3.39	0.07	0.56	0.07		0.07
32	85.05	7.46	2.70	60.89	86.11	1.07	7.09	3.73	2.73	0.10	0.81	0.05	..	0.05
40	85.0	...	3.21	59.7	85.5	1.8	..	3.32	3.18	0.11	0.87	0.10		0.10
9	82.87	7.36	3.26	62.95	82.27	1.10	7.27	2.85	2.45	0.07	0.74	...		0.07
1	81.55	7.20	4.38	61.12	81.32	2.14	7.18	2.06	3.23	[illegible]	0.61	0.06	0.02	0.08
23	79.1	...	...	61.30	78.9	0.8	...	3.55	2.45	0.09	0.85	0.07		0.07
47	80.92	...	...	50.51	80.78	0.88¶	...	6.07	2.59	0.16	1.47	0.05		0.05
11	84.3	...	...	58.7	84.5	0.9	...	3.64	3.08	0.11	1.02	0.06	0.01	0.07
29	83.79	7.31	..	52.99	84.17	1.06¶	7.12	4.10	3.14	0.13	1.15	0.06	0.01	0.07
39	82.80	...		51.73	82.80	0.80	..	4.36	2.23	0.10	0.92	0.04	0.01	0.05
4	82.65	...	..	61.83	83.78	1.46¶	...	2.45	2.42	[illegible]	0.50	0.07	0.01	0.08
18	82.93	7.59	..	63.45	83.29	1.72	7.40	1.24	2.52	[illegible]	0.25	0.11	0.02	0.13
1927	84.54	7.39	3.59	63.10	84.87	1.46	7.30	2.22	2.34	[illegible]	0.42	. .		0.076
1926	85.67	...	...	64.04	85.78	1.14	...	2.67	2.47	0.07	0.50	. .		0.081
1925	86.15	...		63.65	86.27	1.07	...	2.28	2.23	0.05	0.58			0.079
1924	86.18		. .	63.32	86.32	1.27		2.26	2.16	[illegible]	0.37			0.086
1923	85.37		...	63.26	85.65	1.38		2.31	2.22	[illegible]	0.40			0.087
1922	84.74	..	...	63.37	84.96	1.23	...	2.57	2.65	0.07	0.53			0.084
1921	83.74	...	...	62.09	83.90	1.13	...	1.66	2.58	0.04	0.33			0.074
1920	85.03	..	...	61.34	85.20	1.33	...	1.65	2.63	0.04	0.31			0.071
1919	85.46	...	...	62.42	85.70	1.41	...	1.34	2.32	0.03	0.22		..	0.076
1918	85.36	...	...	61.66	85.78	1.79	...	1.48	2.36	0.03	0.26			0.072

COMMERCIAL SUGAR Polarization	CS % Moisture	CS Weight per 100 cane	CS Pol. per 100 cane	CS Pol. per 100 pol. of cane	CS Pol. per 100 pol. of juice	CS Total weight in thousand tons	Factory No.	FINAL MOLASSES Weight per 100 cane	FM Sucrose per 100 cane	FM Sucrose per 100 pol. of cane	FM Sucrose per 100 pol. of juice	FM Gravity solids	FM Gravity purity	FM True purity	OTHER KNOWN LOSSES Pol. per 100 cane	OKL Pol. per 100 pol. of cane	UNDETERMINED LOSSES Pol. per 100 cane	UL Pol. per 100 pol. of cane	Factory No.	Factory
97.43	0.74	13.42	13.08	90.25	92.70	63	6	2.99	1.03	7.14	7.33	86.69	39.89	....	...	...	...	—0.04	6	H. C. & S. Co.**
97.79	0.50	11.73	11.47	89.79	92.13	65	20	2.76	0.96	7.54	7.73	91.36	38.26	....	0.06	0.48	—0.12	—0.99	20	Oahu
97.55	0.51	11.61	11.33	89.59	91.25	52	5	3.05	0.97	7.70	7.85	90.77	35.22	....	...	...	0.06	0.47	5	Ewa
97.54	0.62	11.77	11.48	88.16	90.50	45	17	2.60	0.91	6.97	7.16	92.83	37.61	....	...	...	0.24	1.82	17	Waialua
97.49	0.67	13.46	13.12	89.93	92.55	42	21	3.27	1.13	[illegible]	[illegible]	91.61	37.79				—0.07	—0.51	21	Maui Agr.**
97.49	0.61	10.78	10.32	86.78	89.71	34	36	3.01	1.04	8.78	[illegible]	89.34	[illegible]				0.05	0.41	36	Olaa
97.66	0.51	12.51	12.22	89.50	91.77	39	10	3.21	1.04	7.64	[illegible]	[illegible]	[illegible]				0.01	0.10	10	Pioneer
97.65	0.59	13.39	13.07	91.72	94.23	30	16	2.79	0.92	6.44	6.61	[illegible]	[illegible]				—0.17	—1.22	16	Haw. Sug.
97.04	0.82	10.30	9.99	88.56	91.16	38	27	2.86	0.90	7.98	[illegible]	90.89	[illegible]					[illegible]	27	Lihue
97.53	0.68	10.12	9.88	90.46	91.81	24	34	2.66	[illegible]	7.85	[illegible]	[illegible]	[illegible]	42.36			[illegible]	[illegible]	34	Onomea
....	...	....	....	....	....	31†	13	3.31	1.20	9.05	9.34	93.50	38.70	....	...	...	...	...	13	Honolulu
97.26	0.69	10.41	10.13	90.10	91.98	21	33	2.63	0.84	7.47	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	33	Hilo
97.33	0.69	11.58	11.28	86.90	88.48	29	25	3.77	1.26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	25	Kekaha
97.37	0.70	9.89	9.63	85.93	89.14	21§	30	3.09	1.00	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	30	Haw. Agr.††
96.61	0.90	10.50	10.14	90.77	91.97	19	7	2.88	0.87	7.75	7.85	85.80	35.01	....	...	...	...	0.04	7	Hakalau††
97.20	0.67	12.35	12.00	89.42	90.99	20	2	3.11	1.11	[illegible]	[illegible]	91.44	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	2	Wailuku
97.65	0.69	9.18	8.96	84.89	88.73	19	14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	14	Makee
97.48	0.77	8.66	8.44	85.46	89.25	18	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	35	Honokaa††
97.72	0.65	11.69	11.31	88.11	91.03	16	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	12	McBryde
97.09	0.74	10.94	10.62	87.16	89.82	17	41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	41	Laupahoehoe††
97.16	0.60	11.44	11.12	88.69	91.28	13	15	3.10	0.96	7.66	7.88	81.15	38.19	....			0.10	0.81	15	Hamakua**
97.78	0.57	9.70	9.49	88.82	90.90	15	43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	43	Kahuku
97.40	0.59	10.27	[illegible]	89.66	91.84	12	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	19	Pepeekeo
97.09	0.57	9.40	[illegible]	86.21	88.49	12§	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	24	Paauhau
97.65	0.52	10.62	[illegible]	89.91	91.69	10	37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	37	Honomu
97.74	0.67	10.20	9.97	87.66	90.67	12	38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	38	Koloa
96.90	0.86	9.84	9.53	82.87	86.89	11	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	3	Waiakea
97.30	0.62	9.16	8.91	82.05	85.99	9§	31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	31	Hutchinson††
96.74	0.77	[illegible]	[illegible]	85.61	[illegible]	9	26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	26	Hawi
97.10	0.78	[illegible]	[illegible]	85.84	89.27	9	32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	32	Kaiwiki
96.96	0.62	[illegible]	[illegible]	87.11	[illegible]	8	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	40	Kohala
96.89	0.58	[illegible]	[illegible]	79.99	82.66	5	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	9	Waianae
96.90	0.70	10.00	[illegible]	88.43	90.18	9§	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	1	Waimanalo
97.56	0.69	[illegible]	[illegible]	82.10	85.23	7§	23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	23	Kilauea††
97.41	...	8.74	8.52	79.59	83.78	5	47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	47	Kaeleku
96.41	1.12	9.46	9.12	82.78	89.05	3	11	2.49	0.96	8.72	9.38	88.47	43.61	....	...	...	0.05	0.44	11	Union Mill
96.64	0.87	9.55	[illegible]	82.26	88.78	2	29					91.30	40.0				1.04	9.25	29	Halawa
[illegible]	...	[illegible]	[illegible]	[illegible]	[illegible]	2	39					[illegible]	[illegible]				[illegible]	[illegible]	39	Niulii
97.12		[illegible]	[illegible]	83.56	[illegible]	3	4										[illegible]	[illegible]	4	Waimea
96.39	1.01	[illegible]	[illegible]	81.35	83.20	3	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	18	Olowalu
97.40	0.65	[illegible]	[illegible]	88.26	90.76	802	1927	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	1927	
97.30	0.68	[illegible]	[illegible]	88.62	91.13	782	1926	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	1926	
97.22	0.75	[illegible]	[illegible]	89.11	91.59	767	1925	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	1925	
97.18	0.75	[illegible]	[illegible]	88.94	91.39	696	1924	[illegible]	[illegible]	7.41	7.62	[illegible]	[illegible]	...			[illegible]	[illegible]	1924	
96.90	0.83	[illegible]	[illegible]	88.77	91.28	532	1923	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....			[illegible]	[illegible]	1923	
96.88	0.87	11.64	11.24	87.02	89.68	558	1922	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	1922	
96.75	0.92	11.62	11.24	85.86	88.03	502	1921	[illegible]	[illegible]	9.27	9.51	[illegible]	[illegible]				[illegible]	1.97	1921	
96.36	0.97	12.32	11.87	87.35	89.56	547	1920	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	....					1920	
96.34	0.96	12.59	[illegible]	88.57	90.96	590	1919	[illegible]	[illegible]	7.24	7.42	[illegible]	[illegible]	..			....	...	1919	
96.53	0.94	11.75	11.34	87.91	90.37	557	1918	[illegible]	[illegible]	7.96	[illegible]	[illegible]	[illegible]	...					1918	

* Before heating.
† Refined sugar.
‡ For one tandem only.
¶ Probably influenced by low grade sugar in syrup.
§ 1927 crop unfinished.
** Petree process.
†† Balance of 1926 crop included.

CANE MILL DATA, SEASON OF 1927

Factory	Factory No.	MILLING PLANT (Sizes in Inches)	Revolving Knives, First Set: Number	First Set: Distance Apart Inches	First Set: Distance from Conveyor Inches	First Set: Revolutions per Minute	Second Set: Number	Second Set: Distance Apart Inches	Second Set: Distance from Conveyor Inches	Second Set: Revolutions per Minute	Mill Openings: Crusher	1st Mill Front	1st Mill Back	2nd Mill Front	2nd Mill Back	3rd Mill Front	3rd Mill Back	4th Mill Front	4th Mill Back	5th Mill Front	5th Mill Back
H. C. & S. Co.	6	K(2),2RC34x78,S72,12RM34x78	28	9 3/4	24	1,200	56	5	16	1,200	1/8	7/16	1/16	5/16	1/32	5/16	0	7/16	0	....	....
" "	6	K(2),2RC34x78,S72,12RM34x78	28	9 3/4	24	1,200	48	5	16	1,200	1/16	7/16	1/16	5/16	1/32	5/16	0	7/16	0	....	....
Oahu	20	K,2RC34x78,S72,12RM34x78	26	5	19	490	..	....	....	....	1/8	3/8	0	3/4	0	5/8	0	1/2	0	....	....
"	20	K,2RC34x78,S72,12RM34x78	28	4 1/2	18	690	..	....	....	....	1/4	3/8	0	11/16	0	5/8	0	1/2	0	....	....
Ewa	5	K(2),2RC33x78,18RM34x78	72	2	16	580	72	2	2	580	3/8	3/4	1/16	3/4	1/16	3/4	1/16	3/4	1/8	1/2	0 †
Waialua	17	K(2),2RC33x78,12RM34x78	72	1 7/8	14	580	72	1 7/8	2 1/2	580	1	1/4	0	3/16	0	1/4	0	1/4	0	....	....
Maui Agr.	21	K(2),3RC34x66,12RM34x66	72	7/8	10	450	72	7/8	7/8	520	7/8x1/4	3/8	0	1/2	0	3/16	0	1/16	0	....	....
"	21	K(2),3RC34x66,12RM34x66	72	7/8	10	450	72	7/8	7/8	520	7/8x1/4	3/8	0	1/2	0	3/16	0	1/16	0	....	....
Olaa	36	K,S72,12RM34x78	36	3 13/16	4 1/2	450	..	....	....	....	....	1	3/16	11/16	1/8	7/16	0	5/16	0	....	....
Pioneer	10	K,2RC34x72,S72,15RM34x72	27	2 1/4	16	690	..	....	....	....	1/8	7/16	1/16	7/16	0	7/16	0	7/16	0	7/16	0
Haw. Sug.	16	K,2RC28x72,S72,12RM34x78	32	4	15	450	..	....	....	....	1/4	5/8	1/16	3/8	0	5/16	0	1/4	0	....	....
Lihue	27	K,2RC34x78,S72,12RM34x78	10	7	10	425	..	....	....	....	1/8	1/2	1/16	3/8	0	5/16	0	1/4	0	....	....
Onomea	34	2RC28x60,S54,12RM32x66	..	....	....	....	..	....	....	....	1/8	1/2	1/8	7/16	0	3/8	0	3/8	0	....	....
Honolulu	13	K(2),S54,2RC34x78,9RM34x78	24	6	18	450	24	6	4	500	3/16	3/4	1/2	1/2	0	3/8	0	....	....	....	....
Hilo	33	K,2RC24x60,12RM32x66	10	6	10	200	..	....	....	....	1/4	5/8	1/32	3/8	0	3/16	0	3/8	0	....	....
Kekaha	25	2RC24x54,15RM32x60	..	....	....	....	..	....	....	....	7/8	7/8	1/4	11/16	1/8	5/8	1/16	1/2	1/16	1/2	1/32
Haw. Agr.	30	3RC32x60,12RM32x66	..	....	....	....	..	....	....	....	1x5/8	1/4	1/4	5/8	0	9/16	1/16	1/4	0	....	....
Hakalau	7	2RC24x54,12RM9-32x60,3-32x66	..	....	....	....	..	....	....	....	0	3/4	0	1/4	0	1/8	0	1/4	0	....	....
Wailuku	2	K,2RC28x72,12RM34x78	10	6	18	400	..	....	....	....	1/8	3/8	0	3/8	0	5/16	0	1/4	0	....	....
Makee	14	2RC34x72,S72,9RM34x72	..	....	....	....	..	....	....	....	0	7/16	0	3/8	0	3/8	0	....	....	....	....
Honokaa	35	K(2),2RC30x66,12RM32x66	16	4	14	400	16	4	4	500	1/2	1/2	3/32	7/16	1/32	3/8	0	1/4	0	....	....
McBryde	12	K,2RC34x72,S72,9RM34x84	24	8	16	400	..	....	....	....	1/4	7/16	0	3/8	0	1/4	0	....	....	....	....
Laupahoehoe	41	K,2RC30x54,9RM32x60	16	3 3/4	1	450	..	....	....	....	7/16	3/8	0	3/16	0	1/8	0	....	....	....	....
Hamakua	15	K,2RC30x60,12RM32x60	32	4	2	400	..	....	....	....	1/4	1/2	0	1/2	0	3/8	0	3/16	0	....	....
Kahuku	43	K,2RC30x60,S54,9RM34x72	10	5 1/2	25 1/2	430	..	....	....	....	7/16	5/16	0	3/16	0	1/4	0	....	....	....	....
Pepeekeo	19	2RC24x54,9RM32x60	..	....	....	....	..	....	....	....	1/8	3/4	0	3/16	0	1/8	0	....	....	....	....
Paauhau	24	2RC26x60,12RM32x66	..	....	....	....	..	....	....	....	0	3/8	0	1/4	0	3/16	0	1/8	0	....	....
Honomu	37	3RC33x60,9RM32x60	..	....	....	....	..	....	....	....	1/2x0	3/8	0	3/16	0	3/16	0	....	....	....	....
Koloa	38	K,2RC27x60,12RM32x66	12	4 1/2	8	300	..	....	....	....	3/16	5/8	1/4	1/2	1/8	3/8	0	1/4	0	....	....
Waiakea	3	K,2RC27x60,9RM32x60	36	6	3	385	..	....	....	....	0	1/2	0	3/16	0	1/8	0	....	....	....	....
Hutchinson	31	2RC30x60,9RM32x60	..	....	....	....	..	....	....	....	3/4	1/2	0	3/16	0	1/8	0	....	....	....	....
Hawi	26	K,2RC29x54,12RM30x54	22	4 3/4	9	625	..	....	....	....	3/8	5/16	1/8	3/16	1/16	3/16	0	1/8	0	....	....
Kaiwiki	32	K,2RC24x60,9RM32x60	18	3	3	350	..	....	....	....	1/2	7/16	0	5/16	0	5/16	0	....	....	....	....
Kohala	40	K(2),3RC30x60,9RM32x60	12	4	18	375	36	1 1/2	1 1/2	400	5/8x3/8	3/8	0	1/4	0	3/16	0	....	....	....	....
Waianae	9	K,12RM9-30x60,3-32x60	36	2 1/2	10	400	..	....	....	....	....	3/4	1/4	1/2	1/8	7/16	0	5/16	0	....	....
Waimanalo	1	K,3RC31x54,9RM30x54	28	1 7/8	3 1/2	514	..	....	....	....	5/8x1/16	5/16	0	3/16	0	1/8	0	....	....	....	....
Kilauea	23	K,3RC32x60,9RM32x60	10	6	2	250	..	....	....	....	7/16x3/16	5/16	1/8	1/4	0	1/8	0	....	....	....	....
Kaeleku	47	K,2RC26x54,9RM32x60	9	6	8	250	..	....	....	....	1/8	3/4	1/16	1/4	0	1/8	0	....	....	....	....
Union Mill	11	K,9RM30x60	14	4	5	320	..	....	....	....	....	19/32	0	3/16	0	1/16	0	....	....	....	....
Halawa	29	K,2RC30x60,6RM26x50	20	4 1/2	1/2	390	..	....	....	....	1/4	1/4	0	3/16	0	....	....	....	....	....	....
Niulii	39	K,9RM30x54	9	6	4 1/2	525	..	....	....	....	....	7/16	1/16	1/4	1/32	1/8	0	....	....	....	....
Waimea	4	2RC24x48,12RM26x42	..	....	....	....	..	....	....	....	0	1/2	0	7/16	0	1/4	0	1/4	0	....	....
Olowalu	18	K,3RC28x48,9RM27x48	16	3	3	400	..	....	....	....	3/8x0	5/16	0	1/4	0	1/4	0	....	....	....	....

Factory No.	Speed of Rollers—Feet per Minute: Crusher	1st Mill	2nd Mill	3rd Mill	4th Mill	5th Mill	6th Mill	Pressure on Rollers—Tons: Crusher	1st Mill	2nd Mill	3rd Mill	4th Mill	5th Mill	6th Mill	Tons Cane per Hour	Tonnage Ratio	Factory No.	Factory
6	30	25	24	30	24	...	...	300	400	375	460	460	...	...	59.47*	1.69	6	H. C. & S. Co
6	30	25	24	31	24	...	...	300	400	375	460	460	...	...			6	" "
20	30.7	26.5	18.3	20.9	21.4	...	...	247	579	523	532	517	...	...	65.52*	1.86	20	Oahu
20	30.7	25.5	17.6	20	20.7	...	...	228	523	427	437	388	...	...			20	"
5	22.7	21.7	21.9	25.2	24.7	28.2	32.3	353	450	462	462	383	408	502	85.34	1.73	5	Ewa
17	23.5	22	18.5	21	22.5	...	...	300	500	500	520	520	...	...	78.10	2.22	17	Waialua
21	23	23.5	25.5	28	23.5	...	...	450	340	350	450	260	...	...	47.69*	1.89	21	Maui Agr.
21	23	23.5	25.5	28	23.5	...	...	450	340	350	450	260	...	...			21	"
36	...	21.4	24.5	28.5	32.2	...	...	...	350	320	350	405	...	...	61.21	2.17	36	Olaa
10	51.9	30.1	31.3	28.1	28.1	31.4	...	298	486	440	359	350	377	...	78.35	2.18	10	Pioneer
16	28	17.6	19.8	19.1	21.6	...	...	300	475	450	450	475	...	...	52.68	1.50	16	Haw. Sug.
27	47.8	24.7	24.7	24	27	...	...	290	470	410	430	450	...	...	72.48	2.06	27	Lihue
34	32.2	21.6	21.3	21.6	21.8	...	...	...	428	420	400	420	...	...	48.24	1.91	34	Onomea
13	22.4	21.1	24	25.8	...	...	...	250	450	450	450	...	...	...	47.20	1.68	13	Honolulu
33	34.9	24.5	23.3	26.4	17.9	...	...	...	395	395	395	430	...	...	45.48	1.80	33	Hilo
25	21	16	17.7	19	20	20	...	...	320	315	348	328	356	...	44.27	1.77	25	Kekaha
30	21.5	20	17.5	19.5	21.7	...	...	355	384	457	279	440	...	...	47.37	1.88	30	Haw. Agr.
7	30.5	21.6	24.2	26.5	15.8	...	...	...	322	322	345	380	...	...	33.87	1.63	7	Hakalau
2	29	18.8	15	16.9	19.3	...	...	190	426	410	390	418	...	...	40.90	1.16	2	Wailuku
14	25.9	22.5	25.7	29.5	...	...	...	250	450	475	475	...	...	...	48.60	2.02	14	Makee
35	34.2	24.5	20.2	24.6	27.1	...	...	200	360	370	380	390	...	...	41.40	1.64	35	Honokaa
12	26	18	18	18	...	...	...	250	450	495	520	...	...	...	39.33	1.20	12	McBryde
41	19.6	20.9	18.8	20.9	...	...	...	250	374	374	374	...	...	...	27.64	1.66	41	Laupahoehoe
15	30.5	19.6	19.7	20.1	24.2	...	...	...	380	370	370	400	...	...	30.34	1.46	15	Hamakua
43	31.5	17.2	19.5	22.6	...	...	...	135	540	440	490	...	...	...	38.44	1.60	43	Kahuku
19	31.4	21.7	23.7	26.1	...	...	...	...	385	385	385	...	...	...	28.01	1.68	19	Pepeekeo
24	20.1	14.1	17.3	19.3	20.3	...	...	...	399	383	353	396	...	...	27.45	1.09	24	Paauhau
37	20.4	17.6	20.2	22.4	...	...	...	295	318	318	318	...	...	...	24.67	1.48	37	Honomu
38	24.8	17.3	19	17.6	19.5	...	...	...	400	400	400	400	...	...	35.60	1.41	38	Koloa
3	33.1	22.4	24	27.7	...	...	...	135	335	344	344	...	...	...	25.38	1.52	3	Waiakea
31	27.4	18	19.9	22	...	...	...	65	404	327	398	...	...	...	33.95	2.04	31	Hutchinson
26	34	24.8	23.2	26	26	...	...	117	325	378	325	350	...	...	28.94	1.71	26	Hawi
32	22.3	17.7	19.8	22.4	...	...	...	...	318	308	295	...	...	...	28.18	1.69	32	Kaiwiki
40	25	18	20	25	...	...	...	...	350	340	360	...	...	...	26.92	1.61	40	Kohala
9	...	18.9	17.9	17.9	18	...	...	...	311	320	332	354	...	...	25.27	1.52	9	Waianae
1	18.9	18.4	18	18	...	...	...	350	350	350	350	...	...	...	26.42	1.96	1	Waimanalo
23	18	19.5	26.5	20.5	...	...	...	300	320	310	312	...	...	...	24.5	1.47	23	Kilauea
47	25.7	17.9	19.9	22	...	...	...	...	300	329	354	...	...	...	32.31	1.94	47	Kaeleku
11	...	...	...	...	...	...	...	...	335	287	321	...	...	...	21.54	1.72	11	Union Mill
29	15.9	17.5	14.1	...	...	...	...	100	189	239	...	...	...	...	13.89	1.60	29	Halawa
39	...	19.8	21.2	21.2	...	...	...	...	209	218	212	...	...	...	17.55	1.73	39	Niulii
4	20.4	13.2	14.1	13.6	17	...	...	...	215	...	154	154	...	...	15.45	1.51	4	Waimea
18	23.1	23.1	26.1	26.1	...	...	...	200	200	220	220	...	...	...	17.77	1.66	18	Olowalu

* Tons of Cane for one tandem.
† 6th Mill Openings ¼x0.

TABLE NO. 10

SUMMARY OF LOSSES

FACTORY	POUNDS POLARIZATION PER TON OF CANE						POLARIZATION PER 100 CANE						POLARIZATION PER 100 POLARIZATION OF CANE						Syrup Purity	FACTORY
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL		
H. C. & S. Co. . . .	7.6	. . .	20.6	. . .	. . . .	28.2	0.38	. . . .	1.03	. . . .	. . . . .	1.41	2.65	0.01	7.14	. . . .	—0.04	9.76	87.34	H. C. & S. Co.
Oahu	6.6	1.6	19.2	1.2	—2.4	26.2	0.33	0.08	0.96	0.06	—0.12	1.31	2.55	0.63	7.54	0.48	—0.99	10.21	85.53	Oahu
Ewa	4.6	1.0	19.4	. . .	1.2	26.2	0.23	0.05	0.97	. . . .	0.06	1.31	1.82	0.42	7.70	. . . .	0.47	10.41	84.20	Ewa
Waialua	6.8	1.2	18.2	. . .	4.8	31.0	0.34	0.06	0.91	. . . .	0.24	1.55	2.59	0.46	6.97	. . . .	1.82	11.84	86.2	Waialua
Maui Agr.	8.2	. . .	22.6	. . .	—1.4	29.4	0.41	. . . .	1.13	. . . .	—0.07	1.47	2.83	. . . .	7.75	. . . .	—0.51	10.07	86.18	Maui Agr.
Olaa	7.8	1.8	20.8	. . .	1.0	31.4	0.39	0.09	1.04	. . . .	0.05	1.57	3.27	0.73	8.78	. . . .	0.44	13.22	85.4	Olaa
Pioneer	6.8	0.8	20.8	. . .	0.2	28.6	0.34	0.04	1.04	. . . .	0.01	1.43	2.48	0.28	7.64	. . . .	0.10	10.50	84.61	Pioneer
Haw. Sug.	7.6	1.2	18.4	. . .	—3.4	23.8	0.38	0.06	0.92	. . . .	—0.17	1.19	2.66	0.39	6.44	. . . .	—1.22	8.27	87.39	Haw. Sug.
Lihue	6.4	1.4	18.0	. . .	. . . .	25.8	0.32	0.07	0.90	. . . .	. . . . .	1.29	2.85	0.62	7.98	. . . .	—0.01	11.44	81.8	Lihue
Onomea	3.2	0.4	17.2	. . .	0.2	21.0	0.16	0.02	0.86	. . . .	0.01	1.05	1.47	0.15	7.85	. . . .	0.07	9.54	84.27	Onomea
Honolulu	8.2	1.6	24.0	. . .	. . . .	. . . .	0.41	0.08	1.20	. . . .	. . . . .	. . . .	3.08	0.58	9.05	. . . .	. . . . .	. . . .	85.3	Honolulu
Hilo	4.6	0.6	16.8	. . .	0.2	22.2	0.23	0.03	0.84	. . . .	0.01	1.11	2.05	0.32	7.47	. . . .	0.06	9.90	85.59	Hilo
Kekaha	4.6	1.8	25.2	. . .	2.4	34.0	0.23	0.09	1.26	. . . .	0.12	1.70	1.79	0.67	9.71	. . . .	0.93	13.10	83.9	Kekaha
Haw. Agr.	8.0	1.0	21.2	. . .	1.4	31.6	0.40	0.05	1.06	. . . .	0.07	1.58	3.60	0.41	9.41	. . . .	0.65	14.07	84.61	Haw. Agr.
Hakalau	2.8	0.4	17.4	. . .	0.1	20.7	0.14	0.02	0.87	. . . .	. . . . .	1.03	1.30	0.14	7.75	. . . .	0.04	9.23	83.68	Hakalau
Wailuku	4.6	1.0	22.2	0.2	0.4	28.4	0.23	0.05	1.11	0.01	0.02	1.42	1.73	0.39	8.24	0.09	0.13	10.58	85.4	Wailuku
Makee	9.2	1.2	21.4	. . .	0.2	32.0	0.46	0.06	1.07	. . . .	0.01	1.60	4.33	0.57	10.11	. . . .	0.10	15.11	81.8	Makee
Honokaa	8.4	1.0	19.2	. . .	0.2	28.8	0.42	0.05	0.96	. . . .	0.01	1.44	4.28	0.46	9.69	. . . .	0.10	14.53	82.21	Honokaa
McBryde	8.2	0.6	21.6	. . .	0.2	30.6	0.41	0.03	1.08	. . . .	0.01	1.53	3.21	0.23	8.38	. . . .	0.07	11.89	84.97	McBryde
Laupahoehoe	7.2	0.6	16.8	. . .	6.8	31.4	0.36	0.03	0.84	. . . .	0.34	1.57	2.96	0.21	6.90	. . . .	2.77	12.84	87.5	Laupahoehoe
Hamakua	7.2	. . .	19.2	. . .	2.0	28.4	0.36	. . . .	0.96	. . . .	0.10	1.42	2.84	. . . .	7.66	. . . .	0.81	11.31	86.52	Hamakua
Kahuku	4.8	1.2	16.8	. . .	1.0	23.8	0.24	0.06	0.84	. . . .	0.05	1.19	2.29	0.54	7.86	. . . .	0.49	11.18	81.26	Kahuku
Pepeekeo	5.2	0.6	16.8	. . .	0.4	23.0	0.26	0.03	0.84	. . . .	0.02	1.15	2.37	0.27	7.57	. . . .	0.13	10.34	84.1	Pepeekeo
Paauhau	5.4	1.0	21.2	. . .	1.6	29.2	0.27	0.05	1.06	. . . .	0.08	1.46	2.58	0.48	10.02	. . . .	0.71	13.79	83.69	Paauhau
Honomu	4.4	0.6	17.2	. . .	1.0	23.2	0.22	0.03	0.86	. . . .	0.05	1.16	1.94	0.24	7.43	. . . .	0.48	10.09	84.9	Honomu
Koloa	7.6	1.2	20.4	. . .	—1.0	28.2	0.38	0.06	1.02	. . . .	—0.05	1.41	3.32	0.53	8.92	. . . .	—0.43	12.34	82.3	Koloa
Waiakea	10.6	1.6	25.6	. . .	1.6	39.4	0.53	0.08	1.28	. . . .	0.08	1.97	4.63	0.64	11.14	. . . .	0.72	17.13	84.27	Waiakea
Hutchinson	10.0	0.6	23.2	. . .	5.4	39.2	0.50	0.03	1.16	. . . .	0.27	1.96	4.58	0.23	10.66	. . . .	2.48	17.95	84.36	Hutchinson
Hawi	7.8	1.4	25.0	. . .	0.2	34.4	0.39	0.07	1.25	. . . .	0.01	1.72	3.26	0.56	10.45	. . . .	0.12	14.39	82.57	Hawi
Kaiwiki	9.6	2.0	23.4	. . .	0.4	35.4	0.48	0.10	1.17	. . . .	0.02	1.77	3.85	0.81	9.33	. . . .	0.17	14.16	86.11	Kaiwiki
Kohala	7.4	2.2	21.8	. . .	0.1	31.5	0.37	0.11	1.09	. . . .	. . . . .	1.57	3.06	0.87	8.94	. . . .	0.03	12.90	85.5	Kohala
Waianae	8.4	1.4	31.4	. . .	10.6	51.8	0.42	0.07	1.57	. . . .	0.53	2.59	3.23	0.54	12.11	. . . .	4.13	20.01	82.27	Waianae
Waimanalo	4.2	1.4	19.0	. . .	0.6	25.2	0.21	0.07	0.95	. . . .	0.03	1.26	1.94	0.61	8.70	. . . .	0.32	11.57	81.32	Waimanalo
Kilauea	6.8	1.8	25.8	. . .	1.8	36.2	0.34	0.09	1.29	. . . .	0.09	1.81	3.32	0.85	12.55	. . . .	0.88	17.60	78.9	Kilauea
Kaeleku	10.6	3.2	24.8	. . .	5.0	43.6	0.53	0.16	1.24	. . . .	0.25	2.18	5.00	1.47	11.58	. . . .	2.36	20.41	80.78	Kaeleku
Union Mill	15.4	2.2	19.2	. . .	1.0	37.8	0.77	0.11	0.96	. . . .	0.05	1.89	7.04	1.02	8.72	. . . .	0.44	17.22	84.5	Union Mill
Halawa	16.4	2.6	. . . .	. . .	20.8	39.8	0.82	0.13	. . . .	. . . .	1.04	1.99	7.35	1.15	. . . .	. . . .	9.25	17.75	84.17	Halawa
Niulii	13.6	2.0	. . . .	. . .	25.2	40.8	0.68	0.10	. . . .	. . . .	1.26	2.04	6.30	0.92	. . . .	. . . .	11.79	19.01	82.80	Niulii
Waimea	7.6	1.2	. . . .	. . .	30.0	38.8	0.38	0.06	. . . .	. . . .	1.50	1.94	3.23	0.50	. . . .	. . . .	12.71	16.44	83.78	Waimea
Olowalu	5.8	0.6	22.0	. . .	21.0	49.4	0.29	0.03	1.10	. . . .	1.05	2.47	2.22	0.23	8.29	. . . .	7.91	18.65	83.29	Olowalu

Sugar Prices

96° Centrifugals for the Period December 17, 1927, to March 14, 1928

Date		Per Pound	Per Ton	Remarks
Dec.	17, 1927	4.65¢	$93.00	Cubas.
"	27	4.59	91.60	Cubas.
Jan.	4, 1928	4.63	92.60	Porto Ricos, 4.61, 4.65.
"	5	4.58	91.60	Philippines.
"	9	4.61	92.20	Cubas.
"	10	4.58	91.60	Porto Ricos.
"	13	4.52	90.40	Porto Ricos.
"	14	4.49	89.80	Cubas.
"	17	4.46	89.20	Cubas.
"	21	4.43	88.60	Porto Ricos.
"	24	4.415	88.30	Porto Ricos, 4.43; Cubas, 4.40.
"	27	4.40	88.00	Porto Ricos.
"	31	4.33	86.60	Cubas.
Feb.	1	4.27	85.40	Cubas.
"	2	4.24	84.80	Porto Ricos.
"	7	4.27	85.40	Porto Ricos.
"	8	4.24	84.80	Porto Ricos.
"	14	4.23	84.60	Porto Ricos.
"	15	4.21	84.20	Cubas.
"	18	4.14	82.80	Porto Ricos.
"	20	4.18	83.60	Porto Ricos.
"	23	4.225	84.50	Porto Ricos, 4.21, 4.24.
"	24	4.28	85.60	Porto Ricos, 4.24, 4.27; Cubas, 4.33.
"	27	4.27	85.40	Cubas.
"	28	4.365	87.30	Cubas, 4.33, 4.40.
"	29	4.40	88.00	Porto Ricos.
Mar.	7	4.36	87.20	Porto Ricos.
"	8	4.415	88.30	Philippines, 4.40; Cubas, 4.43.
"	9	4.445	88.90	Porto Ricos, 4.43; Cubas, 4.46.
"	10	4.46	89.20	Porto Ricos.
"	12	4.46	89.20	Porto Ricos.
"	13	4.505	90.10	Porto Ricos, 4.49; Cubas, 4.52.
"	14	4.52	90.40	Cubas.